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STUDY OF SHORT-HAUL AIRCRAFT OPERATING ECONOMICS

FINAL REPORT

VOLUME I

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PREFACE

The study of Short-Haul Aircraft Operating Economics was conducted under the NASA Ames Research Center Contract NAS2-8549. This final report, consisting of two volumes, presents all of the work accomplished by the Douglas Aircraft Company of the McDonnell Douglas Corporation during the six-month study program. The detailed description of the short-haul operating cost model and its substantiating rationale and analysis is contained in Volume I, Final Report (CR 137685). Volume II, Appendix (CR 137686), contains the cost model data base and the applicable explanatory descriptions. The summary and introduction presented in Volume I constitute the executive summary report for this study program.

The principal investigator of the study was Donald A. Andrastek, who was responsible for the design and development of the operating cost model and the related analyses. The Douglas technical director was Joseph Seif, who also was the technical director of the related concurrent NASA study, "Analysis of Operational Requirements for Medium Density Air Transportation".

The study was administered by the Aeronautical Systems Office, NASA Ames Research Center, Moffett Field, California. The Technical Monitors were Joseph L. Anderson and Cynthia L. Smith.

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ABBREVIATIONS, ACRONYMS AND SYMBOLS

AA	American Airlines
acft, ACFT	Aircraft
ACLSE	Aircraft control and line servicing expense
ACOE	Adjusted cash operating expense
ADMTF	Airframe direct maintenance cost, turbofan
ADMTP	Airframe direct maintenance cost, turboprop
ADPE	Amortization of developmental and preoperating expenses
AL	Allegheny Airlines
ALCTF	Airframe direct maintenance labor content, turbofan
ALCTP	Airframe direct maintenance labor content, turboprop
ALFE	Aircraft landing fee expense
ALGW	Fleet average maximum landing gross weight
ATA	Air Transport Association
atkm, ATKM	Available tonne-kilometer
ATSE	Aircraft and traffic servicing expense
B	Billion (10^9)
blk, BLK	Block
blk hr, BLK HR	Block hour
BN	Braniff Airways
BOE	Beverage-only expense
BTPF	Block time per flight
C_e	Cost per engine
C_f	Cost per unit of fuel
C_t	Cost per aircraft
CAB	Civil Aeronautics Board

ABBREVIATIONS, ACRONYMS AND SYMBOLS. - Continued

CAE	Cabin attendants expense
CO	Continental Air Lines
CY	Calendar year
DAC	Douglas Aircraft Company
DFE	Depreciation, flight equipment
DL	Delta Air Lines
DMTF	Total direct maintenance cost, turbofan
DMTP	Total direct maintenance cost, turboprop
DOC	Direct operating cost
DP	Depreciation period
DPC	Design passenger capacity (number of seats)
EA	Eastern Air Lines
EDLTF	Engine direct maintenance labor, turbofan - same as ELCTF
EDMTF	Engine direct maintenance cost, turbofan
EDMTP	Engine direct maintenance cost, turboprop
ELCTF	Engine direct maintenance labor content, turbofan - same as EDLTF
ELCTP	Engine direct maintenance labor content, turboprop
EMMTF	Engine maintenance materials cost, turbofan
ERC	Enplaned revenue cargo
ERP	Enplaned revenue passengers
ERT	Enplaned revenue tons
ESHP	Equivalent shaft horsepower per engine
FBE	Food-and-beverage expense
FCE	Flight crew expense
FCF	Flight crew factor: zero (0) for two-man crew, one (1) for three-man crew
FCR	Fuel consumption rate; e.g., gallons per hour, liters per hour

FL	Frontier Airlines
FO	Flying operations expense
FOT	Fuel, oil and taxes expense
FS	Fleet size (number of aircraft)
ft, FT	Feet, foot
FTPF	Flight time per flight
G&A	General and administrative
GAE	General and administrative expense
GP&E	Ground property and equipment
GPDC	Ground property expense, depreciation content
GPEE	Ground property and equipment expense
GTPF	Ground time per flight
HA	Hawaiian Airlines
hr, HR	Hour
INS	Insurance expense
IOC	Indirect operating cost
IR	Insurance rate
k	Kilo (prefix, 10^3)
kg	Kilogram
km	Kilometer
kN	Kilonewton
ℓ	Liter
LGW	Landing gross weight
lb, LB	Pound
M	Million (10^6)
m	Meter
matls, MATLS	Materials
max., MAX.	Maximum

ABBREVIATIONS AND SYMBOLS. - Continued

MDS	Medium Density Study
MLGW	Maximum landing gross weight
MWE	Manufacturer's weight empty
N	Newton
NA	National Airlines
NASA	National Aeronautics and Space Administration
NC	North Central Airlines
N_e	Number of engines per aircraft
no., No.	Number
NS	Northeast Airlines
n_s	Sample size
NW	Northwest Airlines
OPSE	Other passenger service expense
OWE	Operator's weight empty
OZ	Ozark Air Lines
PASE	Promotion and sales expense
PI	Piedmont Airlines
PREV	Passenger revenue
PSA	Pacific Southwest Airlines
PSE	Passenger service expense
P&WA	Pratt & Whitney Aircraft
r	Correlation coefficient
r^2, R^2	Coefficient of determination
RABH	Revenue aircraft block hours per aircraft per year
RFP	Request for proposal
RAD	Revenue aircraft departures

rakm, RAKM	Revenue aircraft-kilometer
RAM	Revenue aircraft-mile
ROI	Return on investment
rpkm, RPKM	Revenue aircraft-kilometer
RAM	Revenue aircraft-mile
ROI	Return on investment
rpkm, RPKM	Revenue passenger-kilometer
RPM	Revenue passenger-mile
R.R.	Rolls-Royce
rtkm, RTKM	Revenue tonne-kilometer
RTM	Revenue ton-mile
RV	Residual value
RW	Hughes Airwest
SO	Southern Airways
stat. mi., STAT. MI.	Statute mile
STOL	Short takeoff and landing
s	Standard error of estimate
TF	Turbofan
TOC	Total operating cost
TOGW	Takeoff gross weight
TP	Turboprop
TS	Aloha Airlines
TSE	Traffic servicing expense
TSLS	Thrust, sea level static maximum, per engine
TT	Texas International Airlines
TW	Trans World Airlines
UA	United Airlines

ABBREVIATIONS, ACRONYMS AND SYMBOLS. - Concluded

U.S.	United States
USG	U.S. gallons
VDC	Design cruise speed at design cruise altitude
WA	Western Air Lines
W_a	Airframe weight
W_e	Engine weight, per engine
yr, YR	Year
$	Dollars
¢	Cents
%	Percent

SUMMARY

Many methods of documenting and evaluating transport aircraft operating economics have evolved since Mentzer and Nourse, of United Airlines, published, in 1940, their classic treatise on the economic aspects of transport aircraft performance. Some of these economic methods have been primarily for engineering and technology applications while others have been oriented toward the market research and airline financial aspects of air transportation.

The desire for a universal transport aircraft operating cost model for technology evaluation will never be fulfilled because it could never anticipate, let alone meet each and every requirement imposed upon it. The short-haul operating cost model developed as part of this study is not intended to be an end result nor universal application, but instead it is the first attempt to model this part of the air transportation field. It will form the basic building block for future evolutionary development.

Objectives

The objectives of this study were to develop an improved capability for analysis of the operating economics of short-haul air transportation systems, and to identify the effect of such factors as level of service provided, traffic density of the market, stage length, number of flight cycles, level of automation, as well as aircraft type and other operational factors on direct and indirect operating costs.

Data

The study analyzed airline operating data of 1971-1973 from the Civil Aeronautics Board (CAB) Form 41, "Uniform System of Accounts and Reports",

and developed from these data, normalized to 1973, an operating cost model (not a computer program) which included items and factors unique to short-haul operations. To best reflect the operating costs of short-haul operations, the direct operating costs (DOC) were based on a range of transport aircraft currently used by the domestic trunk and regional airlines (DHC-6 to B727-200). The indirect operating costs (IOC) were based on the operating statistics and costs of eight local service and two regional airlines. The DOC and IOC cost-estimating relationships (CERs) resulting from the operating cost analysis were combined to form the short-haul operating cost model.

Cost Model

A group of 25 CERs describe all the cost elements of the annual direct and indirect operating costs of a short-haul airline. These CERs are mathematical expressions relating operating costs to various air transport system characteristics, and are designed to be used for conceptual aircraft evaluation purposes only. The model output, for each CER as well as for the total DOC and total IOC, are expressed in constant 1973 dollars. Appropriate airline industry price indices can be used to restate these costs in current dollars.

The DOC CERs of a fleet of either turboprop or turbofan aircraft were based on 18 independent variables. These determine the five major direct operating cost elements of flight crew, fuel-oil-and-taxes, insurance, flight equipment maintenance, and flight equipment depreciation. These cost element-independent variable relationships include:

- Flight Crew: maximum takeoff gross weight, design cruise speed, flight crew size.

- Fuel-Oil-and-Taxes: fuel consumption rate, unit fuel cost.
- Maintenance, Flight Equipment: airframe weight, number of engines per aircraft, engine unit cost, maximum equivalent shaft-horsepower per engine (for turboprop aircraft), maximum sea-level-static thrust per engine (for turbofan aircraft), aircraft flight time per flight.
- Depreciation, Flight Equipment: aircraft unit cost, depreciation period, residual value.

The IOC CERs which estimate the annual operating costs of a fleet of short-haul aircraft have six IOC cost elements determined by eight independent variables, either individually or in combination, as follows:

- Passenger Service: revenue passenger-miles, enplaned revenue passengers.
- Aircraft and Traffic Servicing: revenue aircraft-miles, fleet revenue aircraft departures, fleet-average maximum landing gross weight, revenue ton-miles.
- Promotion and Sales: enplaned revenue passengers, revenue passenger-miles.
- Ground Property and Equipment: flight equipment depreciation expense.
- Amortization: revenue aircraft-miles.
- General-and-Administrative: adjusted cash operating expense.

The short-haul operating cost model was designed for studies such as are performed by the NASA in systems studies. Its structural format and content is sensitive to this requirement. However, with proper judgment and use of input variables, it is capable of providing economic insight into

other short-haul transport system evaluations. While it could be used with discretion for airline efficiency analysis, it was not designed for, nor is it recommended for such use.

The model, and its supporting data, should be considered as an initial effort which, through further and deeper studies, will become broader and more sophisticated. Since this is the first attempt to comprehensively model the operating costs of short-haul air transportation, the analytic methods employed and the CERs developed might be expected to change somewhat with future studies.

The model was tested with input data which was descriptive of short-haul aircraft design and operations. Two airlines, Air California and United Airlines, provided assistance in the conduct of the study and furnished regular assessment of Douglas' work to assure its airline realism and viability.

Conclusions

The following significant conclusions were derived from this study of short-haul aircraft operating economics:

- The short-haul operating cost model can provide for comparative analysis purposes a standard method for estimating the direct and indirect costs of contemporary turbine powered transport aircraft operating in a typical, short-haul environment.
- The model provides more realistic operating costs of short-haul air transport systems than any of the current domestic trunk oriented DOC and IOC models or methods.
- The results of the aircraft maintenance cost analysis from the system-level approach and for the types of aircraft studied do not agree with the 1967 Air Transport Association maintenance cost method which is related to flight-hour and flight-cycle as variables.

- The level-of-service changes in passenger service expense, for example the difference between a food-and-beverage and a beverage only service, can be determined.
- The model will evaluate the effect on operating cost due to changes in stage length brought about by aircraft performance changes, for example, block fuel or block time (or speed).
- The model, since it was designed for air transport system-level evaluation, cannot adequately measure the traffic-density effect on operating costs.
- Automation improvements of passenger and baggage handling could lower operating costs slightly.

Recommended Research Programs

Recommendations for future study were identified from an evaluation of the study results. Areas requiring more research and study effort include:

(1) Expand the capability of the existing cost model to permit trend analysis and forecasting.

(2) Conduct an in-depth analysis of the flight crew expense and aircraft maintenance expense elements of the short-haul cost model.

(3) Conduct an in-depth analysis of the passenger service, aircraft servicing, and traffic servicing expense elements of the short-haul cost model.

(4) Develop the operating cost model capability for analyzing intra-state and commuter airline operations.

(5) Develop an operating cost model for analyzing domestic trunk operations.

INTRODUCTION

Background

Technology advances in commercial transport aircraft have usually resulted in increases in aircraft productivity and corresponding decreases in direct operating costs per seat-mile or per ton-mile. However, productivity and unit direct operating costs do not adequately indicate the economic viability of a given aircraft. This requires a more comprehensive costing approach which realistically portrays the total operating costs, direct and indirect, of an aircraft within the context of an airline environment.

Studies of short-haul air transportation systems lacked the capability to determine realistic operating costs because the costing methods were based on long-haul operations of the U.S. domestic trunk airlines. This applied both to the Air Transport Association (ATA) method for determining aircraft direct operating costs (DOC), and to the Lockheed/Boeing method for determining indirect operating costs (IOC). Adjustments to the methods were frequently employed but these did not always provide consistent and confident results.

Some method for evaluating the DOC of transport aircraft has been in existence since 1944, when the first universally recognized method was published by the ATA. This method, originally based on DC-3 actual operations, has been subsequently updated through four revisions, culminating in the last one, published in 1967. This last revision reflected experience with the DC-8/B707-type aircraft in long-haul, trunk airline operations. It also included some factors and criteria for estimating supersonic transport (SST) operational cost.

The history of IOC methodology development is more recent. It had its beginning in 1964 during the early phases of the U.S. SST development program. The first method, developed jointly by Boeing and Lockheed, resulted from a Federal Aviation Administration (FAA) requirement for an adequate, universally adaptable method to determine IOC so as to enhance the SST evaluation process. This method has been updated by Lockheed to incorporate more recent trunk airline operating experiences. Since the original method was based on long-haul passenger operations, it has also been revised so as to reflect the operational costs of cargo airlines. Most recently, Boeing has incorporated a methodological change which more closely paralleled the Civil Aeronautics Board (CAB) Form 41 accounting and reporting system.

Several other DOC and IOC methods have been used in aircraft and airline evaluations. The NASA and Industry Transonic Transport studies (1971) used for its IOCs the CAB costing methodology developed during the Fare Level Phase of the Domestic Passenger Fare Investigation. The NASA Quiet STOL Systems studies (1972-73) performed by Lockheed and McDonnell Douglas used the 1967 ATA method for DOC and the Lockheed-California method for IOC. However, each of these methods required extensive subjective adjustments to make them usable and to accurately reflect high-density, short-haul operations. Another IOC model, generated in 1968 by the Flight Transportation Laboratory of MIT, was based on both domestic trunk and local service airline operations. It did not include all the indirect operating expense items within the CAB Form 41 accounting system. It was not very applicable, for it was probably intended for evaluating high-speed rail transportation systems since it was done for the Office of High Speed Ground Transport of the Department of Transportation.

The reductions in the unit total operating costs (DOC + IOC) of the local service and regional air carriers during the 1960s due to technological innovations have been dramatically reversed in the early 1970s by the rapidly increasing labor and material costs. The two to threefold increase in unit fuel cost over the past two years is a case in point. The capability to evaluate the interplay between technology and economics in short-haul aircraft design, development, and operation is mandatory in today's rapidly changing air transportation environment. Better quantitative methods for cost and economic analysis in that area of air transportation are required.

Because short-haul air transportation is receiving considerable attention at many government levels, it is necessary to have a current operating cost method that adequately describes that particular form of airline operation. The NASA recognized the need for determining viable short-haul aircraft operating costs, and, in 1974, issued a Request for Proposal (RFP) for a six-month study of short-haul aircraft operating economics. This report documents the results of that study.

Objective

The basic objective of this study was to define and develop an operating cost method or model that was unique to short-haul aircraft operations. Rather than just a simple extension or alteration of previous domestic trunk (long-haul) oriented DOC and IOC methods, it was to be new, based on actual operational cost data and which accurately portrayed the total operating costs of short-haul operations. This study and resultant model were to identify, to the extent possible, the effect of factors such as level of service provided, traffic density of the market, stage length, number of flight cycles, aircraft type and other operational factors on

direct and indirect operating costs.

A secondary objective of this study was to assess the cost impact of future automation on the total operating expenses of short-haul air transportation systems. Areas of application for automated ground equipment were to be identified and the impact of this automation on operating costs evaluated.

The operating cost model was to be designed for use by the NASA to provide an up-to-date capability for evaluating short-haul transport aircraft concepts.

Approach

The analysis performed during this six-month study covered the entire spectrum of direct and indirect cost elements comprising total airline operating costs as reported in the CAB Form 41 Uniform System of Accounts and Reports for Certificated Air Carriers. Because of the number of elements examined, each and every cost element could not be examined in great depth. However, this was not an unacceptable constraint since the study weighed its effort in proportion to the impact of each element, and it was able to produce a model, containing some 25 cost-estimating relationships (CER), which could estimate the operating costs of short-haul aircraft in a typical airline environment.

In keeping with study guidelines that limited the analysis to U.S. short-haul routes under 500 statute miles (805 kilometers), the airlines used were restricted to the eight local service and the two Hawaiian regional airlines as representative of short-haul operations. This group of air carriers has about 95 percent of its stage lengths under 500 statute miles (805 kilometers). By comparison and based on analysis of 1973 operations,

only 55 percent of all domestic trunk stage lengths are less than this distance. This stage length distribution, coupled with the fact that the CAB Form 41 reporting system does not permit the separation of the direct operating costs by stage length nor the separation of indirect operating costs by aircraft type, influenced the decision to base the short-haul operating cost model primarily on only local service and regional airline operations and costs.

This short-haul operating cost model is comprised of a direct operating cost model and an indirect operating cost model. The direct and the indirect operating cost models estimate the annual operating costs. Each CER in these two models produces a cost estimate in terms of millions of 1973 dollars per year. The DOC model was based on the operational and cost data of all short-haul turbine transports currently in local service and regional airline operation. In addition, the operational and cost data of the BAC-111, B737, DC-9, and B727 transports operated by the domestic trunks in short-haul, passenger-carrying operations were incorporated whenever possible into the DOC model to enhance its predictive capability for larger aircraft. The CERs in the DOC model are constructed so that single aircraft direct operating costs can easily be determined.

The IOC model was developed from only the operational and cost data of the local service and regional airlines. Data describing just the short-haul operations of the domestic trunks is not available from the CAB Form 41 reporting system. If it had been available it would have been incorporated to enhance the indirect operating cost model.

This study did not require the development of a computer program. The study consisted of collecting and analyzing the data for the cost model,

determining the dependent and independent variables, developing the model, and verifying the results. Special attention was given in this study to the documentation; thus, not only the analysis of these data but also the data base have been included. The data covered the three-year period from 1971 through 1973; it was normalized to 1973, and the base for the model is 1973.

The most significant factor concerning the study was that actual data as reported by the airlines dictated the shape and content of this cost model. An intimate understanding of the CAB Form 41 reporting system and its contents was required to appreciate the subtleties in the data and how that data might best be interpreted to develop the model.

1.0 SHORT-HAUL OPERATING COST MODEL

1.1 Background

The direct and indirect operating cost (DOC & IOC) models developed over the past 15 years were researched, reviewed, and evaluated to establish the proper basis for a short-haul operating cost model. The evaluation of these models involved objectives, design, cost elements considered, type of methodology, and eventual use.

In addition, past NASA-contracted aircraft and systems studies, such as the advanced technology transport, advanced supersonic transport, and short-haul, quiet, turbofan STOL (short takeoff and landing) transport, were reviewed to determine how existing operating cost models were used to evaluate new transport aircraft concepts. The operating cost models which were used in these studies had one thing in common; they were all based on U.S. domestic trunk airline data for either domestic and/or international operations. For most of these types of studies, the use of existing trunk-oriented operating cost models proved adequate for evaluation purposes; however, the STOL systems studies required extensive subjective adjustments to the 1967 ATA DOC method (ref. 1) and the Lockheed-California IOC method (ref. 2) to make the existing models accurately reflect high-density, short-haul operations.

The existing operating cost models represent domestic trunk operations over all stage lengths: short, medium, and long. Short-haul operations, the subject of this study, are normally those aircraft stage lengths that are less than 500 statute miles (805 kilometers). Since the U.S. airlines do not report their expenses on a stage-length basis, it had never been possible to build an operating cost model which accurately described only short-haul operations.

The widely used Air Transport Association (ATA) method for estimating comparative direct operating costs of transport aircraft does provide a means for determining the variation of cost with aircraft range (or stage length). The most recently published edition (1967) upgraded the 1960 method by providing cost equations based on several years of domestic trunk DC-8 and B707 operations. It was published too early to incorporate the trunkline and regional airline experience with DC-9 and B727 type aircraft, since these aircraft did not operate in significant quantities until the late 1960's.

A significant change in the DOC methodology occurred from 1960 to 1967. The direct maintenance cost in the 1960 method was estimated on a block-hour basis, while the 1967 method incorporated an approach which broke the total direct maintenance cost inter per-flight-cycle and per-flight-hour components. Research into some of the analysis behind the flight-cycle and flight-hour allocation method did not provide adequate substantiation to accept that rationale for use in the development of the short-haul operating cost model. As a result, the short-haul operating cost model determines aircraft direct maintenance on a different basis. It is based on the actual operating costs of contemporary short-haul turbine transports over a recent three-year period. Sections 2.1.4 through 2.1.8 provide a description of the method that was used.

Indirect operating cost models developed over the past 10 years were designed primarily to provide a level of cost detail equivalent to that of the ATA DOC method, so that total operating costs (DOC + IOC) would more accurately reflect actual aircraft and airline operations. However, indirect operating costs are "system-oriented" costs; that is, they are indicative of the airline as a whole, and cannot readily be reduced to a per-airplane or a

per-airplane-mile basis as the ATA DOCs. In addition, the IOC models developed by both Boeing and Lockheed were based entirely on trunkline operational and cost data as reported by the airlines to the CAB. As a result, these models did not accurately portray short-haul operations, since the trunklines are primarily medium-to-long haul air carriers.

The research into past operating cost models concluded that no composite model (i.e., DOC and IOC) existed which was approprate for evaluating short-haul air transportation. The cost model developed as part of this study should provide the NASA with that capability. The planning, development, and verification of the short-haul operating cost model is described in the following sections.

1.2 Scope

Parameters which might be used to indicate the economic worth of a transport aircraft concept can vary from relatively simple direct operating costs, stated either as a function of stage length or at the aircraft design payload-range point, to complex economic criteria, such as return-on-investment, which can require an extensive analysis of airline revenues and expenses over some period of time. Because of study scope limitations, the model developed as part of this study will only encompass direct operating expenses and indirect operating expenses.

The relationship of direct and indirect operating expenses to the total airline economic model is shown in Figure 1-1. It is based on the CAB definition of revenue and expense. The two major operating cost elements which comprise the short-haul operating cost model are shown within the cross-hatched bounded area. The other expense category, Non-operating Expenses,

consists of expenses such as interest, taxes, and mutual aid payments, and was not considered in the development of the cost model.

The direct and indirect operating cost elements used in the short-haul operating cost model conform to the elements of the CAB Form 41 accounting system (ref. 3) used by the airlines for reporting purposes. A fundamental ground rule for the development of the cost model was that the data used for the analysis and to develop the cost-estimating relationships (CER) were to be actual operating cost data as submitted by the U.S. certificated airlines. In this analysis, and in the cost model, the terms expenses and costs are used synonymously.

Another constraint, imposed during the development of the cost model, was that the model was to estimate annual costs only at the total-airline level. In order to cover the breadth of operating cost categories contained in "total operating costs" within the study scope, certain cost elements could not be extensively investigated. This constraint did not limit the capability of the cost model, but it did limit its applications to the total airline system level. It should not be used, for example, for detailed aircraft trade studies.

The selection of the appropriate airlines and aircraft to best represent short-haul operations were influenced by the type of operational and cost data contained in the CAB Form 41 reporting system and by certain study constraints. The airlines were selected as follows. The eight local service and the two Hawaiian regional airlines were selected to best represent short-haul operations. These air carriers have about 95 percent of their stage lengths under 500 statute miles. By comparison, only 55 percent of all domestic trunk stage lengths are less than this distance. This is based on

analysis of 1973 operations. This type of stage-length distribution, and the fact that the CAB Form 41 reporting system does not permit the separation of the direct operating costs by stage length nor the separation of indirect operating costs by aircraft type, influenced the decision to base the short-haul operating cost model primarily on regional airline operations and costs. The domestic trunk airlines flying short-haul aircraft types (average stage lengths $\leq$ 500 statute miles) were also included in the development of the DOC model to enhance its predictive capability for larger aircraft.

Three tables have been compiled to show the CAB Form 41 schedules, the airlines, and the aircraft types which formed the study data base. Table 1-1 lists the eleven Form 41 schedules which provided the operational, traffic, and cost data for the analysis and the cost model. Schedules P-9.2 and T-3 were selected specifically for the analysis of the economic impact of automation, a required task of the study. The automation analysis is discussed in Section 5.0. Table 1-2 lists the airlines used for the study. The local service and the Hawaiian regional airlines were grouped together and called short-haul regional airlines. The trunklines, as noted previously, provided selected aircraft operational and cost data for the short-haul DOC model. The contemporary transport data base for the DOC model, with aircraft type matched to type of operation, is detailed in Table 1-3. An objective of the study was to model turboprop as well as turbofan short-haul aircraft operations.

A study constraint requiring all costs to be stated in 1974 dollars was rescoped to make 1973 the base year of the cost model. This was done because CAB Form 41 data for the complete 1974 calendar year was unavailable at the outset of the study. An additional influence was the difficulty in determining appropriate price indices to restate these costs in future-year

dollars, particularly during the current period of airline cost uncertainty. The complete data base for the analysis and for the model was comprised of three calendar years of airline operations: 1971, 1972 and 1973. This three-year period was chosen to eliminate data irregularities which often occur when just one particular year is selected to represent typical airline operations. The cost-estimating relationships which make up the short-haul DOC and IOC models were designed to produce operating cost estimates in terms of millions of 1973 dollars per year.

Since the model is built around existing and uniform expense and operational data extracted and processed from CAB Form 41 accounts, data exclusion could occur. The ultimate objective of short-haul operating cost model, such as the one resultikng from this study, is to estimate operating costs for any type of scheduled airline operation: trunkline, local service, intra-state, or commuter. But the CAB Form 41 data for domestic trunk airlines does not permit cost allocation by segment length, and a data base similar to the CAB Form 41 does not exist for intra-state and commuter airlines. Thus the model represents a regional airline type of operation and does not provide credible estimates of other types of airline operations.

The transport aircraft operating spectrum represented by this cost model is indicated by the cross-hatch area shown in Figure 1-2. The airline groups used for the DOC and IOC models are indicated. As discussed previously, the local service airlines and the two Hawaiian regional airlines formed the primary basis of the short-haul operating cost model, with selected short-haul trunkline transports added to enhance the DOC model. This was done to comply with study objectives.

1.3 Approach

Previous transport operating cost models were examined to determine what types of dependent and independent variables were included in them. It was concluded that, rather than to be a simple extension of previous domestic trunk (long-haul) oriented DOC and IOC methods, the cost model would employ new analytic approaches, based on actual operational and cost data, to accurately portray the total operating costs of short-haul operations to the major functional categories of the CAB system for reporting DOC and IOC information.

To facilitate the analysis of a tremendous amount of data in a short time period, the CAB Form 41 data on the computer tapes of the National Archives and Records Service (NARS) were processed and compiled to create the specialized data base required for this study. This task was accomplished after an extensive evaluation and review of CAB hard-copy and microfilm-library data concluded that a computer-compiled data bank would provide the most cost-effective solution to the study data requirement. This compilation of CAB Form 41 data is included as Appendix B of this report. The data-to-model transition underlying the development of the DOC and IOC models is depicted in Figure 1-3.

The development of each cost-estimating relationship (CER) followed an orderly process in which each major functional cost category was first evaluated in depth to determine which independent variables most appropriately described that function from an air transportation point-of-view. The relationships between these operating costs and the appropriate air transport system and/or aircraft characteristics were then graphically evaluated to determine which independent variables (individually, or in combination) would

best describe each individual operating cost element. The independent variables showing the best correlation were then incorporated into a cost-estimating relationship, one for each cost element where that approach was warranted, using accepted statistical techniques such as correlation and regression. Twenty-five individual CERs were developed which comprise the short-haul operating cost model. These were all mathematical expressions which can easily be computer-programmed for large-scale air transportation studies, where extensive aircraft and system evaluations must be performed in a short period of time.

The DOC model is comprised of 13 CERs which depict airline operating costs of turboprop and turbofan aircraft. The selection of cost elements for this part of the short-haul operating cost model was influenced by the cost elements and the controlling variables of ATA DOC method. Although the basic estimating relationships describing each cost element (e.g., flight crew cost, insurance costs, turbofan direct maintenance cost, etc.) have dimensions paralleling those of the ATA DOC method (dollars per block hour or dollars per flight), each CER was expanded to produce an annual airline operating cost so that the DOC and IOC models would have similar types of output.

The IOC model also represents the airline operating costs of a short-haul operation, based on regional airline experience over the 1971-73 time period. This model incorporates 12 CERs which describe the annual indirect operating costs of a typical short-haul airline, based on three years of regional airline experience, 1971 to 1973. The controlling variables in the short-haul IOC model are similar to but not as extensive as the variables incorporated in previous trunkline-oriented IOC models. However, this IOC model does accurately reflect the indirect operating costs of a regional,

short-haul airline, using airline system-operational parameters such as revenue passenger-miles, enplaned revenue passengers, and revenue aircraft departures.

The DOC and IOC model development process is presented in Figure 1-3, and described in Sections 2.1 and 2.2.

To evaluate the effect of automation on IOCs, an additional analysis was conducted, as is illustrated by the flow diagram at the bottom of Figure 1-3. This task evaluated data from two CAB Form 41 schedules, P-9.2 and T-3, to determine whether or not the cost impact of automation could be determined from existing CAB data, and what level of analysis could be undertaken and what types of conclusions could be reached within the scope of the study. The ground servicing or station expense analysis, based on the data of P-9.2 and T-3, is discussed in Section 1.4.5. This analysis was limited to just the 1973 operations of selected regional airlines. It was based on information compiled from CAB Form 41 microfilm data banks, since the National Archives and Records Service does not compile Schedule P-9.2 data in its CAB data processing system. The description of the impact of automation on IOC from an airline operations approach is contained in Section 5.0 of this report.

The development phase of the short-haul operating cost model was followed by a verification phase in which the model was tested and evaluated to assure its realism relative to producing representative short-haul operating costs. This phase included review and comments by Air California and United Airlines. A case study was conducted with the model to test the input variables required to operate the model and to check the model output for consistency, numerical correctness, and accuracy. This case study used input data which was indicative of a typical short-haul regional airline operating

a fleet consisting of one type of short-haul, turbine-powered transport. Since this cost model is not a computer model, the case study was calculated by hand and was limited to only one test case.

Additional testing was performed during the development of the short-haul DOC and IOC models. All of the CERs of the IOC model were derived using statistical correlation methods such as simple linear regression, multiple linear regression, and power curve fitting. The decision-making parameters used to select the best independent variables were (1) coefficient of correlation, (2) coefficient of determination, (3) standard error of estimate, and (4) F-value for analysis of variance. These testing parameters were used to indicate how well the mathematical expression describing each IOC element "fit" the actual regional airline cost data from which it was derived. The development of the DOC model employed various types of model-building techniques, including some of the statistical methods used to construct the IOC model.

Two types of comparisons were conducted to evaluate the usability of the cost model. The output data from the case study was compared to the actual regional airline operating costs for 1973 of those airlines whose size and operating characteristics most closely matched the "typical" airline of the case study. The second type of evaluation involved the use of this cost model as an alternative costing methodology for independent in-house studies of similar areas of air transportation. These latter two comparisons and the case study are discussed in Section 3.0.

The applicability of the short-haul operating cost model is discussed in detail in Section 4.0. Included in this section are statements

concerning the predictive capability of the cost model and the limitations inherent in a model of this type. Analysis which would increase the scope and complexity of the model is also discussed.

1.4 Data Base

This section discusses the development of the data base required to build the short-haul operating cost model. This discussion includes an overview of the CAB Form 41, Uniform System of Accounts and Reports, and a description of the process used to build the data bank for the cost model. Also included in this section are the operating expense analyses of the retional airlines and the domestic trunks which were used to form and guide the conceptual development of the model. The ground servicing expense analysis based on data from the P-9.2 and T-3 schedules of CAB Form 41 is presented next. This analysis was conducted to determine the level of depth to which the more comprehensive automation analysis, discussed in Section 5.0, should be carried out.

1.4.1 CAB Form 41, Uniform Systems of Accounts and Reports. The model structure, the type of cost elements, is based on and is compatible with the reporting procedures of the CAB Uniform System of Accounts and Reports. This reporting system was adopted by the CAB on July 1, 1938, and has been progressively updated to the current edition, dated January 1, 1973. This last edition (ref. 3) was the basic reference document for this study.

Under this CAB reporting system, all airline operating expense items are given both a functional and objective account designation. The first two digits of an expense account code indicate the function or activity

which created and is responsible for that particular expenditure. Typical functional activities are maintenance, aircraft servicing, and passenger service. The second two digits of an expense code refer to the objective, or item, for which a particular expenditure was made. Typical objective accounts are the various salary or labor accounts, the various material accounts, rentals, and taxes.

The summary functional groupings of airline operating expense as used by the CAB Form 41 system are shown in Table 1-4. For each grouping, the four-digit functional account code and the Form 41 schedule in which that account appears are indicated. This is the cost element structure used to define the cost elements of the short-haul operating cost model. These summary cost groupings can be further broken down into detailed functional groups, such as that illustrated in Table 1-5 for the "Flying Operations (Less Rentals)" expense. For each of these detailed functional groups is comprised of certain objective expense accounts, and can be identified with the appropriate four-digit code, as shwon in Table 1-5. A listing of all objective accounts contained within each summary functional grouping, together with the appropriate numerical codes, is included in Appendix A of this report.

The expenses reported in the P-schedules are cumulative expenditures on a monthly, quarterly, or yearly basis. The derivative of commonly used unit operating costs such as center per available ton-mile requires data to be extracted and compiled from the appropriate traffic (or "T") schedules. The three T-schedules used for this study were T-1, T-2, and T-3. The type of data compiled from each of these schedules is listed in Table B-3 of Appendix B.

1.4.2 CAB Accounts-to-Cost Model Correlation. The short-haul operating cost model follows the current CAB definition of direct and indirect operating expenses. The CAB separation of total operating expense into direct and indirect components, by major functional account, is shown in Table 1-6. The four major functional accounts comprising DOC are the same categories as used in the ATA method to define aircraft direct operating costs. This alignment of the Form 41 functional elements into DOC and IOC thus defines the elements of the short-haul operating cost model.

1.4.3 Evaluation and Analysis. The development of the data bank involved an extensive evaluation and analysis of the entire CAB Form 41 data system prior to the actual development of the cost model. This evaluation and analysis involved a series of steps which included extraction, collation, reduction, adjustment and verification.

An evaluation of actual CAB Form 41 hard-copy and microfilm library data was conducted as the first step toward compiling the particular data elements required for this cost model. A sample of 1970, 1971, 1972 and 1973 operating cost and traffic data for the domestic trunks and the regional airlines was evaluated to determine which schedules, cost and traffic elements, airlines, and calendar reporting periods would be computer-compiled to form the actual data base for the study and for the model. This step was necessary since every objective cost account in each summary functional cost account would not be used for the economic analysis and subsequent formulation of the operating cost model.

The most cost-effective method for compiling the model data bank was to use the CAB Form 41 data of the National Archives and Records Service

(NARS), a part of the General Services Administration, which provides computer tapes of the CAB data on a subscription basis. Douglas is a subscriber to this service, and has existing computer compilation programs to access and aggregate the data. The 115 pages of computer-compiled NARS data describing the 1971, 1972 and 1973 operations and costs of the domestic trunk and regional airlines, as developed for the study, are included in Appendix B. Appropriate descriptors and keys to reading the data are included in Appendix B.

It was originally intended to use data from four successive years (1970 through 1973) in the development of the model, but in mid-1970 a format change in the CAB traffic and aircraft operating data (the T-schedules) prohibited using present computer programs to access, compile and correlate the earlier data. The decision was made to reduce the data base to three years (1971 to 1973). Some aggregate data summaries for 1970 were available from other sources, and these were used, when appropriate, during the data evaluation phase.

The CAB hard-copy data and the computer tapes of the National Archives and Records Service both describe the same airline operations and costs, and are normally considered reliable sources for data. However, a considerable number of discrepancies in the data banks of these two sources were discovered when compiling the specialized data bank used to build the short-haul operating cost model. Examples of these discrepancies are:

CAB Hard Copy Data - Column totals do not match the sum of the individual elements.

- Quarterly summations for the year do not match the annual totals.

- Totals for the same expense function varying from schedule to schedule.

NARS Tape Data

- Traffic data for certain quarters were omitted.
- Cost accounts for certain quarters were omitted.
- Function totals agree with hard copy data but subfunctions disagree.
- Inconsistent tabulations of aircraft departure data (possibly an airline submission error).
- CAB data transfer error: hard copy-to-tape. Example: $105,192 instead of $1,057,192.

Because of these data inaccuracies, a more than normal amount of verification and analysis was expended to assure the validity of the data base for the model. This data problem was very influential in conceptually designing the cost model since it favored the decision to develop a system-level model instead of one built up from many detailed expense elements (the "bottom-up" approach). In this regard, some desired objectives of the study were not met. For example, a detailed traffic density analysis and its effect on certain expenses, a comprehensive personnel expense analysis to assess effects of automation as well as other aspects of airline operation, and an extensive station cost analysis were considerably reduced in scope or were eliminated as the model development evolved. Thus, the computer compilation was designed to access and compile primarily the summary functional cost accounts. Certain detailed cost accounts within each summary functional account were selected

for compilation on an as-needed basis. The cost model data bank is included in Appendix B.

1.4.4 Operating Expense Analysis. One of the objectives of the study was to be able to explain the effects of variations in traffic, route network, aircraft, and operations on airline operation expenses. In some respects, these variations could not be answered within the data base and the scope of this study. However, certain system-level variations coulbe be accounted for, and these will be explained.

A review and analysis of the total operating expenses of the local service airlines and the two Hawaiian airlines was made to gain insight into the magnitudes and ranges of expense. This effort involved the determination of certain expense ratios, trends, and distributions. Table 1-7 lists the direct and indirect operating expenses and the IOC to DOC ratios for 1973 for the ten regional airlines. This table will give the reader an idea of the dollar amounts of these expenses as well as the range in the IOC/DOC ratio for this airline group. The two Hawaiian airlines fly the shortest stage lengths (120-124 statute miles, 193-200 km), and have the highest IOC/DOC ratios. However, the 0.875 ratio for Southern Airlines has to be explained by something other than average stage length (ASL) since its ASL of 170 miles (274 km) was not the longest of the ten airlines. The longest average stage length was achieved by Allegheny - 218 statute miles (351 km).

The trend in the IOC to DOC ratio over a seven-year period, 1967 through 1973, is shown in Figure 1-4 for the local service airlines, with the same ratio for the domestic trunks included for comparison purposes. The rising trend after 1967 to some degree parallels the price/wage increases on

a national level. The more rapid increases after 1971 could have resulted from many causes, but these will not be discussed here. But, two points of interest should be noted about these trends. First, the ratios for the domestic trunks have always been greater than those for the local service airlines. Perhaps this is caused by a scale-of-operations effect. Secondly, the IOC to DOC ratio for the domestic trunk group did not equal or exceed 1.00 until the 1972-73 period. In many previous conceptual transport cost analyses, the absence of an acceptable IOC method or model frequently resulted in assuming the IOC equal to the DOC to determine total operating cost. This approach, for the years prior to 1972, overstated the total operating costs when based purely on DOC. This also supported the FAA decision in 1963 to have the SST study finalists (Boeing and Lockheed) develop a detailed IOC method of the type and depth of the ATA DOC method.

In the same sense, this study improves on the past, for it produced, for the regional airline group a total operating cost model that permits both a DOC and an IOC assessment of short-haul operations.

The percentage distribution of total operating expense, based on the major CAB functional cost categories, is shown in Table 1-8 for both the domestic trunks and the local service airlines. This data was derived from 1973 operations. Note that the values indicate the percent of total operating expense of each functional group indicated. As an example, the "Maintenance-Flight Equipment" value for the local service airlines is read as 16.5 percent of total operating expense, not as 16.5 percent of DOC. This table was separated into two sections for ease of presentation, and was developed for two reasons. The first was to present a comparison between the major functional operating cost accounts within an airline group and between airline

groups, that is, between the trunks and the local service airlines. The second reasons was important from a model standpoint. The contribution of a particular expense element to the total would indicate the depth of analysis required for each element in relation to the total model development effort. For example, the time spent developing the CER for flight deck crew expense would be significantly greater than that required to develop the CER for insurance expense, since the former element was 14.2 percent of the total operating expense while the latter was only 0.8 percent. This distribution of model development effort assured the appropriate treatment of each operating cost element, since each individual element and its CER were developed on a sequential basis. Thus the level of effort to importance was uniform. The categories whose sub-elements were extensively analyzed and from which the CERs were developed were Flying Operations (5100), Direct Maintenance (5200), Passenger Service (5500), and Aircraft and Traffic Servicing (6400). These expenses represent about 75 percent of the 1973 local service total operating expenses.

1.4.5 Ground Servicing Expense Analysis. The analysis of the impact of automation on airline operating expenses was conducted in two phases. The first phase, discussed here, consisted of a comprehensive overview and evaluation of ground servicing expenses based on CAB Form 41, to determine the practicability of conducting a detailed, bottom-up cost benefit evaluation of automation within the scope of the study. The second phase, discussed in Section 5.0, detailed the actual investigation conducted based on the insight gained from the first phase. This two-phased approach and its relation to the cost model development is indicated by the flow diagram in the lower part of Figure 1-3. The station cost analysis in the figure refers to the first and the automation analysis to the second phase.

The ground servicing expense analysis had several objectives: (1) to determine whether airline cost reporting of this activity was consistent; (2) to determine the allocation rationale used by the airlines in distributing expenses between regional and system expenses and station expenses, and (3) to determine if the data contained in the CAB Form 41 schedules would permit as extensive an investigation of automation as planned at the outset of this study.

The first phase of the automation analysis was conducted using the in-house microfilm library of CAB Form 41 data since the National Archives and Records Service (NARS) computer tape bank used to compile the special data base for the study did not contain schedule P-9.2, the schedule which details the quarterly ground servicing expenses of each airline. This data constraint limited this study phase to just 1973 expense and operating data of certain airlines.

The analysis results are depicted in Tables 1-9 through 1-14. Table 1-9 shows the 1973 indirect operating expense, the ground servicing expense, and the relation of ground servicing to indirect operating expense for the eight airlines evaluated. Ground servicing expenses constitute about 70-75 percent of the regional carriers' indirect operating expenses. United Airlines was included for comparison purposes, and at 63.1 percent was significantly lower. However, the entire group of domestic airlines could not be evaluated to determine if this percentage was indicative of that group.

While the ground servicing percentage of indirect operating expense was fairly consistent for the regional airlines studies, the allocation of ground servicing expense between system and station functions was markedly inconsistent, as indicated in Table 1-10. The station expense percentage, for

example, varied from 43.1 percent for Hawaiian Air to 67.2 percent for North Central Airlines. Extensive in-depth analysis was required to determine the underlying reasons for these wide variations.

The in-depth analysis of ground servicing expense for each of the airlines studied is exemplified by Tables 1-11 and 1-12, which detail and summarize these 1973 expenses for North Central Airlines. Table 1-11 shows the break-out of total annual operating expense into the summary functional indirect operating expense accounts. All expenses incurred in aircraft servicing, traffic servicing, servicing administration, reservation and sales, advertising and publicity, and general ground property direct maintenance and depreciation are allocated to the ground servicing function. Each airline, however, differs in its division of this expense into regional and system expenses and station expenses. Table 1-12 was compiled to show the relationship of ground servicing expense to total operating expense by identifying the functional direct and indirect operating expenses which are subtracted from the total operating expense to obtain the ground servicing portion. The expense definitions are those of the CAB. The account codes and appropriate CAB Form 41 schedules are also indicated.

The station expense percentage distributions among the summary functional accounts for the four regional airlines selected for the in-depth analysis of this activity are shown in Table 1-13. The percentage figures in each column indicate the percent of total station expense of each of the functions shown. For example, the station expense of Hawaiian Air for 1973 is $7.547 million, which is 43.1 percent of its total ground servicing expense, as indicated in Table 1-10. Of that $7.547 million, traffic servicing

comprises 83.9 percent of the total station expense, and aircraft servicing 8.4 percent. This comparison shows quite a variation among this airline group.

The usual objective of automation is to save expense by replacing manual labor with automated machinery. The final step in the cost evaluation of ground servicing entailed the determination of the labor content of the five major indirect operating expense functions: passenger service, aircraft servicing, traffic servicing, reservations and sales, and general and administrative. Calculating the labor percentages of these functions for the four airlines which formed the basis for the in-depth expense analysis gave the results summarized in Table 1-14. The lack of consistent trends among the regional airlines was again evident, as was previously shown in Table 1-13.

The wide differences in ground servicing cost allocation and distribution among the four regional airlines studied in depth would tend to indicate the same trends for the group as a whole. This indication resulted in a re-direction, with NASA approval, of the original automation analysis envisaged for the study. The study's analysis of the effects of automation on operation expenses would thus be restricted to a system level basis.

1.4.6 Cost Model Guidelines. The short-haul operating cost model is a data-based model. The aircraft types used to develop the direct operating cost model are contemporary, fixed-wing, turbine-powered transports. These aircraft ranged in size from the DHC-6 (turboprop) to the B727-200 (turbofan). Their characteristics are summarized in Appendix C. A regional airline group, consisting of the mainland local service airlines plus the two Hawaiian airlines, formed the primary basis for the short-haul operating cost model.

Data for domestic trunk aircraft used primarily for short-haul operations (e.g., DC-9, B737, BAC-111, B727) were included in the development of the DOC model to strengthen the cost-estimating relationships (CER). The cost model is based on 1971, 1972, and 1973 actual airline operations and expenses, as tabulated in the CAB Form 41 Uniform System of Accounts and Reports. The selection of a three-year instead of a one-year period of airline operations to serve as the basis for this cost model ensured that the cyclical variations in airline operations from year to year were adequately accounted.

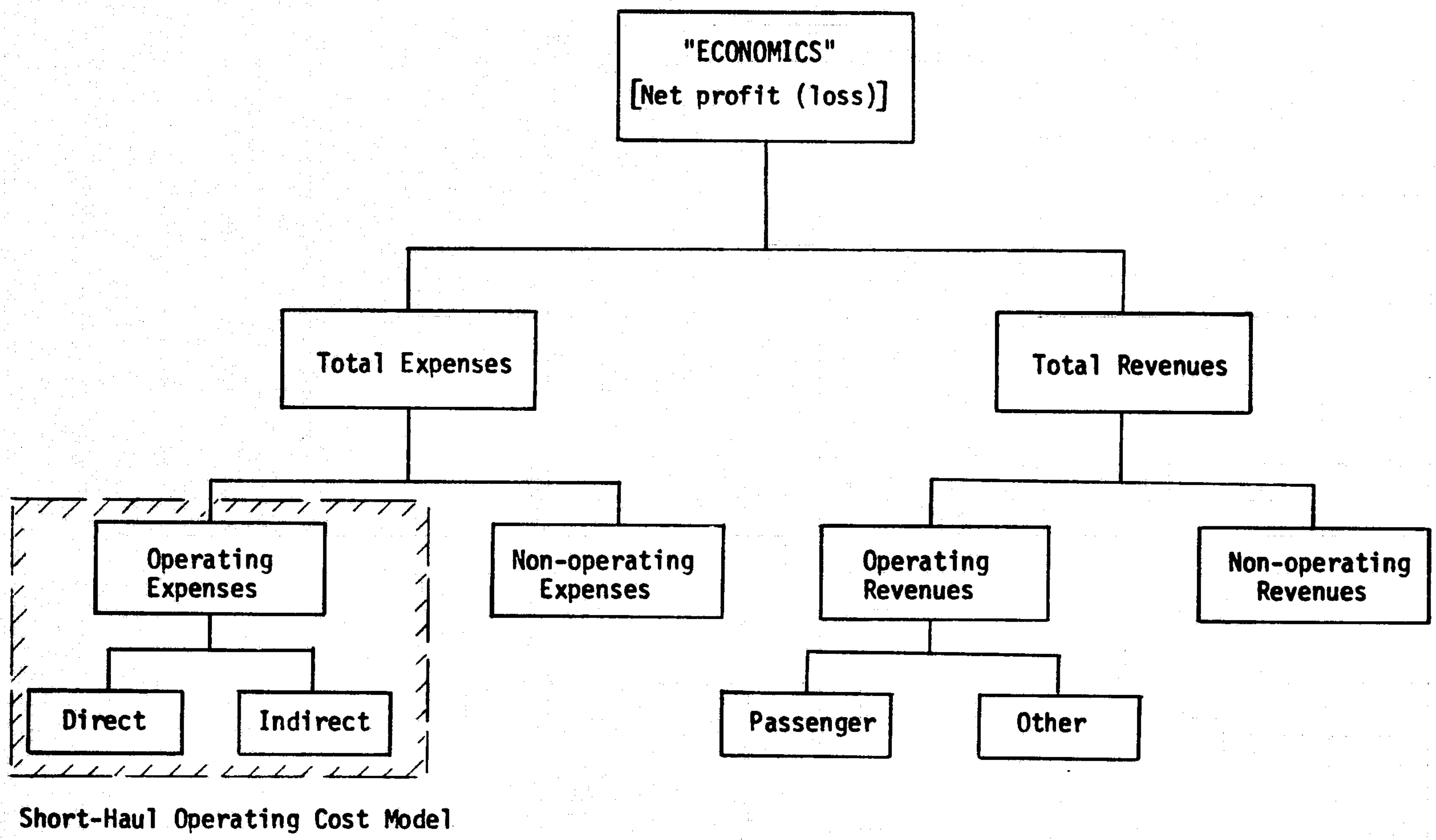

Figure 1-1 - Airline expense and revenue relationship

Type of airline	Aircraft average stage length, stat. mi. (km)		
	< 500(805)	500-1000 (805-1609)	> 1000(1609)
Domestic trunk	[DOC]	DT[a]	--
Local service	HAW LS [DOC, IOC]	--	--
Intra-state	N/A	--	--
Commuter	N/A	--	--
Air taxi (unscheduled)	N/A	--	--

[a] DT - domestic trunks, LS - local service, HAW - Hawaiian airlines; 1973 operations.

Figure 1-2. - Transport aircraft operating spectrum
[Cost model data base]

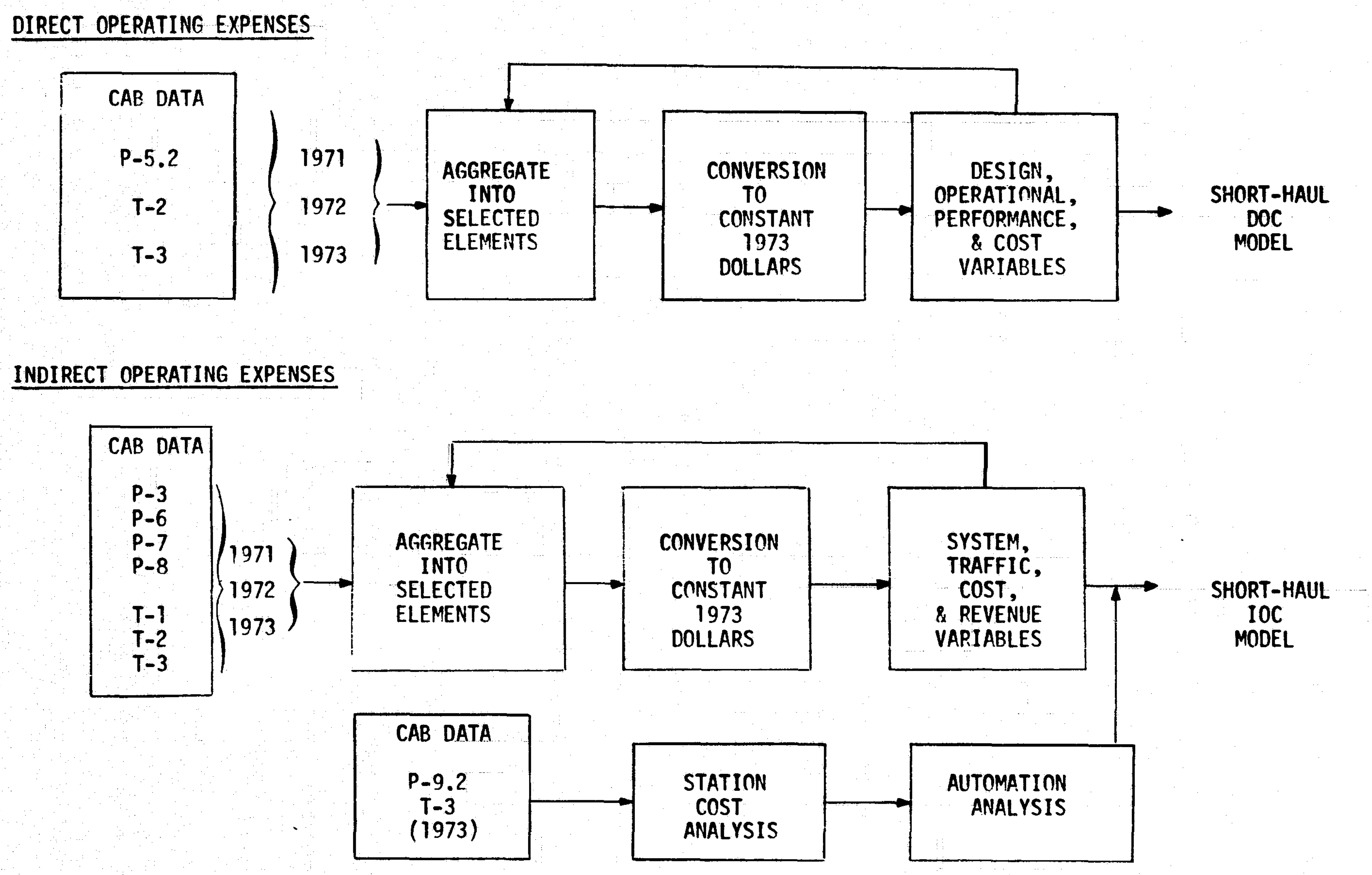

Figure 1-3. - Development process overview

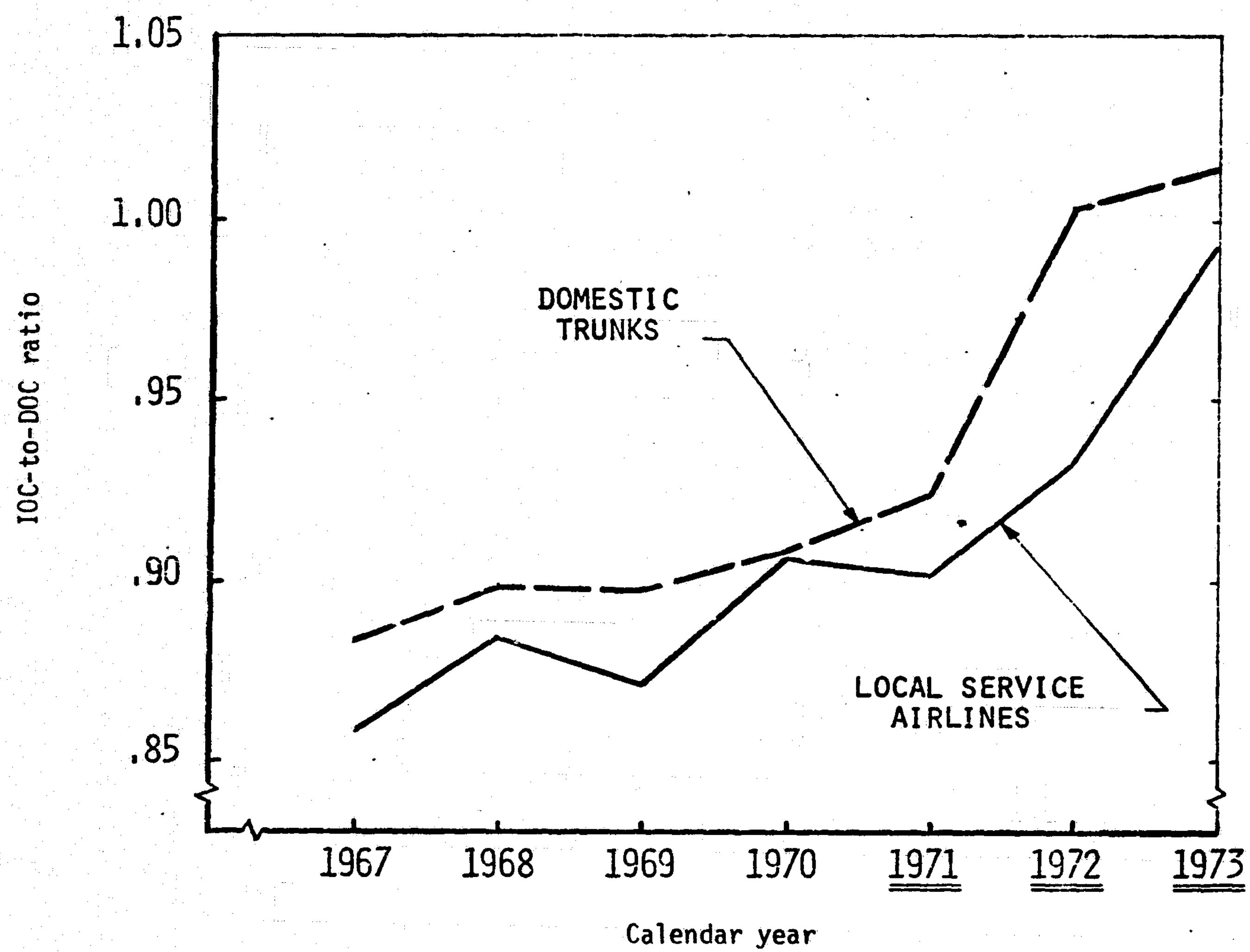

Figure 1-4. - Indirect-to-direct operating cost trends
[Domestic operations]

TABLE 1-1. - SHORT-HAUL OPERATING COST STUDY - DATA BASE

SCHEDULES

P-1.2 .... INCOME STATEMENT

P-3 .... TRANSPORT REVENUES; DEPRECIATION AND AMORTIZATION

P-5.2 .... AIRCRAFT OPERATING EXPENSES

P-6 .... MAINTENANCE, PASSENGER SERVICE, AND GENERAL SERVICES AND ADMINISTRATION EXPENSE FUNCTIONS

P-7 .... AIRCRAFT AND TRAFFIC SERVICING, PROMOTION AND SALES, AND GENERAL AND ADMINISTRATIVE EXPENSE FUNCTIONS

P-8 .... AIRCRAFT AND TRAFFIC SERVICING AND PROMOTION AND SALES EXPENSE SUBFUNCTIONS

P-9.2 .... DISTRIBUTION OF GROUND SERVICING EXPENSES BY GEOGRAPHIC LOCATION

P-10 .... PAYROLL

T-1 .... TRAFFIC AND CAPACITY STATISTICS BY CLASS OF SERVICE

T-2 .... TRAFFIC, CAPACITY, AIRCRAFT OPERATIONS, AND MISCELLANEOUS STATISTICS BY TYPE OF AIRCRAFT

T-3 .... AIRPORT ACTIVITY STATISTICS

TABLE 1-2. - SHORT-HAUL OPERATING COST STUDY - DATA BASE

AIR CARRIERS

DOMESTIC TRUNKS

- AMERICAN
- BRANIFF
- CONTINENTAL
- DELTA
- EASTERN
- NATIONAL
- NORTHEAST
- NORTHWEST
- TWA
- UNITED
- WESTERN

LOCAL SERVICE

- ALLEGHENY
- FRONTIER
- HUGHES AIRWEST
- MOHAWK
- NORTH CENTRAL
- OZARK
- PIEDMONT
- SOUTHERN
- TEXAS INTERNATIONAL

REGIONALS

- ALOHA
- HAWAIIAN AIR

TABLE 1-3. - AIRCRAFT DATA BASE FOR DOC MODEL

1971 - 1973 TIME PERIOD

AIRCRAFT TYPE	DOMESTIC TRUNKS OPERATIONS	LOCAL SERVICE OPERATIONS	REGIONAL OPERATIONS
727-200/100	X	X	-
DC-9-30	X	X	X
DC-9-10	X	X	-
737-200	X	X	X
BAC-111-200	X	X	-
BAC-111-400	X	-	-
CV-580/600	-	X	-
F-27/FH-227	-	X	-
YS-11	-	X	-
DHC-6/B99	-	X	-

TABLE 1-4

AIRLINE OPERATING EXPENSE FUNCTIONS

[CAB Reporting System]

5100[a] .... FLYING OPERATIONS (P-5.2)[b]
- FLIGHT CREW
- FUEL AND OIL
- INSURANCE AND OTHER
- RENTALS (FLIGHT EQUIPMENT)

5400 .... MAINTENANCE

- 5200 .... DIRECT MAINTENANCE
  - FLIGHT EQUIPMENT (P-5.2)
  - GROUND PROPERTY AND EQUIPMENT (P-6)
- 5300 ... MAINTENANCE BURDEN (P-6)
  - FLIGHT EQUIPMENT
  - GROUND PROPERTY AND EQUIPMENT

5500 .... PASSENGER SERVICE (P-6)

6400 .... AIRCRAFT AND TRAFFIC SERVICING

- 6100 ..... AIRCRAFT SERVICING (P-7 & P-8)
- 6200 ..... TRAFFIC SERVICING (P-7 & P-8)
- 6300 ..... SERVICING ADMINISTRATION (P-8)

6700 .... PROMOTION AND SALES (P-7 & P-8)

- 6500 ..... RESERVATION AND SALES
- 6600 ..... ADVERTISING AND PUBLICITY

6800 .... GENERAL AND ADMINISTRATIVE (P-7)

7000 .... DEPRECIATION AND AMORTIZATION (P-3)

7199 .... TOTAL OPERATING EXPENSES (P-1)

(a) FUNCTIONAL ACCOUNT
(b) FORM 41 SCHEDULE

TABLE 1-5. - FLYING OPERATIONS (LESS RENTALS) EXPENSE COMPONENTS

[CAB Definition]

	ACCOUNT
• **FLIGHT CREW EXPENSE**	
PILOTS AND COPILOTS SALARIES	5123
OTHER FLIGHT PERSONNEL SALARIES	5124
TRAINEES AND INSTRUCTORS SALARIES	5128
PERSONNEL EXPENSES	5136
EMPLOYEE BENEFITS AND PENSIONS	5157
PAYROLL TAXES	5168
• **FUEL AND OIL EXPENSE**	
AIRCRAFT FUELS	5145.1
AIRCRAFT OILS	5145.2
TAXES -- OTHER THAN PAYROLL	5169
• **INSURANCE EXPENSE**	
INSURANCE PURCHASED	5155.1
PROVISIONS FOR SELF-INSURANCE	5155.2
INJURIES, LOSS AND DAMAGE	5158
• **OTHER FLYING OPERATIONS EXPENSES**	
PROFESSIONAL AND TECH. FEES AND EXPENSES	5141
OTHER SUPPLIES	5153
OTHER EXPENSES	5171

TABLE 1-6. - OPERATING EXPENSE FUNCTION ALIGNMENT

[CAB Accounting System]

FUNCTION (ACCOUNT NUMBER)	DOC	IOC
FLYING OPERATIONS LESS RENTALS (5100)	●	
MAINTENANCE (5400)		
DIRECT MAINTENANCE (5200)		
FLIGHT EQUIPMENT	●	
GROUND PROPERTY AND EQUIPMENT		●
MAINTENANCE BURDEN (5300)		
FLIGHT EQUIPMENT	●	
GROUND PROPERTY AND EQUIPMENT		●
PASSENGER SERVICE (5500)		●
AIRCRAFT AND TRAFFIC SERVICING (6400)		●
PROMOTION AND SALES (6700)		●
GENERAL AND ADMINISTRATIVE (6800)		●
DEPRECIATION, RENTALS AND AMORTIZATION		
DEPRECIATION AND RENTALS--FLIGHT EQUIPMENT (7000,5100)	●	
DEPRECIATION--GROUND PROPERTY AND EQUIPMENT (7000)		●
AMORTIZATION (7000)		●

TABLE 1-7

1973 TOTAL OPERATING EXPENSE OVERVIEW

[CAB Form 41 da[illegible]]

AIRLINE	OPERATING EXPENSE ($ MILLIONS)			INDIRECT-TO-DIRECT RATIO
	DIRECT	INDIRECT	TOTAL	
ALLEGHENY	160.172	149.219	309.391	0.932
FRONTIER	57.689	58.278	115.967	1.010
HUGHES AIRWEST	57.079	66.744	123.823	1.169
NORTH CENTRAL	53.565	60.854	114.419	1.136
OZARK	(a)	(a)	(a)	(a)
PIEDMONT	51.049	47.099	98.148	0.923
SOUTHERN	43.878	38.403	82.281	0.875
TEXAS INTERNATIONAL	37.867	36.595	74.462	0.966
ALOHA	11.129	15.560	26.689	1.398
HAWAIIAN AIR	18.253	23.638	41.891	1.295

(a) Excluded because of partial operations (strike) during 1973.

TABLE 1-8. - PERCENTAGE DISTRIBUTION OF OPERATING EXPENSES

[Calendar Year 1973]

FUNCTIONAL GROUPINGS	Percent of Total Operating Expense	
	Domestic Trunks	Local Service
DIRECT OPERATING EXPENSES:		
FLYING OPERATIONS (LESS RENTALS)		
FLIGHT DECK CREW	13.0	14.2
FUEL AND OIL	12.0	10.0
INSURANCE AND OTHER	.5	.8
TOTAL FLYING OPERATIONS (LESS RENTALS)	25.5	24.9
MAINTENANCE - FLIGHT EQUIPMENT:		
DIRECT	7.4	10.9
BURDEN	5.9	5.6
TOTAL MAINTENANCE - FLIGHT EQUIPMENT	13.3	16.5
DEPRECIATION AND RENTALS - FLIGHT EQUIPMENT:		
DEPRECIATION	7.9	4.8
RENTALS	3.0	3.9
TOTAL DEPRECIATION AND RENTALS - FLIGHT EQUIP.	10.9	8.8
TOTAL DIRECT OPERATING EXPENSE	49.7	50.2

TABLE 1-8. - PERCENTAGE DISTRIBUTION OF OPERATING EXPENSES - Continued

[Calendar year 1973]

FUNCTIONAL GROUPINGS	PERCENT OF TOTAL OPERATING EXPENSE	
	DOMESTIC TRUNKS	LOCAL SERVICE
INDIRECT OPERATING EXPENSES		
PASSENGER SERVICE	11.2	7.1
AIRCRAFT AND TRAFFIC SERVICING:		
AIRCRAFT SERVICING	8.4	8.3
TRAFFIC SERVICING	9.8	15.9
SERVICING ADMINISTRATION	1.1	1.0
TOTAL AIRCRAFT AND TRAFFIC SERVICING	19.2	25.1
PROMOTION AND SALES:		
RESERVATION AND SALES	9.5	8.6
ADVERTISING AND PUBLICITY	2.3	1.5
TOTAL PROMOTION AND SALES	11.7	10.1
GENERAL AND ADMINISTRATIVE	4.6	5.5
MAINTENANCE AND DEPR. - GROUND PROP. AND EQUIP.		
MAINTENANCE	1.8	1.0
DEPRECIATION	1.4	.6
TOTAL MAINTENANCE AND DEPRECIATION - G.P.& E.	3.2	1.6
AMORTIZATION	.3	.4
TOTAL INDIRECT OPERATING EXPENSE	50.3	49.8

TABLE 1-9

GROUND SERVICING EXPENSE ANALYSIS - 1973 OPERATIONS

[Relation to indirect expense]

AIRLINE	INDIRECT OPERATING EXPENSE	GROUND SERVICING EXPENSE	GROUND SERVICING % INDIRECT
ALLEGHENY	$149.219 M	$107.909 M	72.3%
FRONTIER	58.278	41.430	71.1
ALOHA	15.560	11.693	75.1
HAWAIIAN AIR	23.638	17.504	74.1
NORTH CENTRAL	60.854	44.824	73.7
SOUTHERN	38.401	27.276	71.0
TEXAS INTL.	36.595	26.130	71.4
UAL (DOM)	882.077	556.534	63.1

TABLE 1-10

GROUND SERVICING EXPENSE ANALYSIS - 1973 OPERATIONS

[System-and station-percentages]

AIRLINE	GROUND SERVICING EXPENSE	SYSTEM EXPENSE	STATION EXPENSE
ALLEGHENY	$107.909 M	45.4%	54.6%
FRONTIER	41.430	47.3	52.7
ALOHA	11.693	36.4	63.6
HAWAIIAN AIR	17.504	56.9	43.1
NORTH CENTRAL	44.824	32.8	67.2
SOUTHERN	27.276	45.1	54.9
TEXAS INTL.	26.130	54.8	45.2
UAL (DOM)	556.534	36.4	63.6

TABLE 1-11. - GROUND SERVICING EXPENSE SUMMARY

AIRLINE	YEAR
NORTH CENTRAL	1973

TOTAL OPERATING EXPENSE
$114.419M

INDIRECT OPERATING EXPENSE (SERVICING, SALES AND GENERAL OPERATING EXPENSE)
$60.854M

GROUND SERVICING EXPENSES
$44.824M

REGIONAL AND SYSTEM EXPENSES (INCL. OFF-LINE FACILITIES MAINTAINED OR USED) $14.711M		STATION EXPENSES (INCL. ON-LINE FACILITIES MAINTAINED OR USED) $30.113M
3.272	AIRCRAFT SERVICING (6100) ($8.970M)	5.698
2.915	TRAFFIC SERVICING (6200) ($20.922M)	18.007
0.610	SERVICING ADMINISTRATION (6300) ($2.144M)	1.534
7.274	RESERVATION AND SALES (6500) ($11.045M)	3.771
0.322	ADVERTISING & PUBLICITY (6600) ($0.821M)	0.499
0.318	DIRECT. MAINT. & DEPREC'N.- GENERAL GROUND PROPERTY (5200, 7000) ($0.922M)	0.604

TABLE 1-12. - GROUND SERVICING EXPENSE RECONCILIATION
[North Central Airlines - 1973]

TOTAL OPERATING EXPENSE (Acct. 7199, Sched. P-1)	$ 114.419 M
LESS: TOTAL AIRC. OPERATING EXPENSE (Acct. 7098.9, Sched. P-5.2)	- 53.565
TOTAL INDIRECT OPERATING EXPENSE (Servicing, Sales and General Operating Expense)	60.854
LESS: PASSENGER SERVICE EXPENSE (Acct. 5599, Sched. P-6)	- 8.094
LESS: GENERAL AND ADMIN. EXPENSE (Acct. 6899, Sched. P-7)	- 6.592
LESS: MAINT. BURDEN - GEN. GROUND PROPERTY (Acct. 5379.8, Sched. P-6)	- 0.350
LESS: AMORTIZATION - DEVEL. & PREOP. EXPENSE (Acct. 7074.1, Sched. P-3)	- 0.811
LESS: DEPRECIATION - MAINT. EQUIP. & HANGARS (Acct. 7075.8, Sched. P-3)	- 0.183
TOTAL GROUND SERVICING EXPENSE (Sched. P-9.2 Summary)	$ 44.824 M

TABLE 1-13

STATION (LOCAL) EXPENSE VARIATION

[1973 Operations]

EXPENSE FUNCTION	HAWAIIAN AIR	NORTH CENTRAL	SOUTHERN	TEXAS INTL.
GROUND SERVICING EXPENSE	$17.504 M	$44.824 M	$27.276 M	$26.130 M
PERCENTAGE DISTRIBUTION AT STATION LEVEL ($ REF)	($7.547 M)	($30.113 M)	($14.964 M)	($11.817 M)
AIRCRAFT SERVICING	8.4%	18.9%	27.4%	9.7%
TRAFFIC SERVICING	83.9	59.8	67.7	87.8
SERVICING ADMIN.	2.1	5.1	--	0.1
RESERVATION AND SALES	4.0	12.5	3.9	1.0
ADVERTISING AND PUBLICITY	0.3	1.7	NEGL.	NEGL.
DIR. MAINT. & DEPR. - GEN. GRD. PROP.	1.3	2.0	1.0	1.4

TABLE 1-14

INDIRECT EXPENSE ANALYSIS - LABOR CONTENT [a]

[1973 Operations]

FUNCTION	LABOR CONTENT (PERCENTAGE)			
	HAWAIIAN	FRONTIER	NO. CENTRAL	ALLEGHENY
PASSENGER SERVICE	72.4%	38.6%	48.0%	56.7%
AIRCRAFT SERVICING	75.7	45.1	53.8	36.9
TRAFFIC SERVICING	73.3	79.5	70.2	67.7
RESERVATION AND SALES	38.2	38.5	30.1	46.5
GENERAL & ADMINISTRATIVE	43.0	51.7	42.7	49.4

[a] Wages, salaries and fringe benefits.

2.0 COST MODEL DEVELOPMENT

This ection describes the development of the cost model, including the substantiating analysis and derivation of each cost-estimating relationship (CER). The model, in its final form, expresses total annual operating costs in terms of millions of 1973 dollars per year. This also applies to each CER within the model. The output dimension was chosen to facilitate comparisons with the actual airline operating expense records of the CAB Form 41 reporting system, since all airline operating expenses are reported either on a quarterly or an annual basis. It was also chosen to indicate the relative accuracy of the model. All CERs are calculated in fractional millions of dollars to the nearest $10,000. For example, the calculated annual flight crew expense would be written as $20.66 million. This level of accuracy is sufficient for the type of cost analyses for which the model was designed.

The model output can be re-stated in any dimension desired by the user. For example, the output of the DOC model can also be calculated in the commonly-used units of $/block-hour, $/aircraft-mile; or ¢/available seat-mile. These DOC units are derived and are not reported in CAB Form 41. U.S. Customary Units are used throughout the model development process. All CAB Form 41 data are in these units, and it was beyond the scope of this study to develop elaborate conversion processes for this raw data. However, certain charts and tables will also contain the international system of units (SI) where practicable.

The development of the generalized CERs comprising the cost model followed a sequential process consistent with developing models of this type. Established procedures were used to reduce the CAB Form 41 data to the

appropriate independent and dependent variables. Techniques commonly used in building cost model CERs were selected by the type of cost element being modeled. All cost model elements did not require the application of extensive statistical analysis techniques to develop the CER for that element. These elements, all in the DOC model, were: fuel, oil and taxes; insurance; and flight equipment depreciation. The remainder of the CERs required the application of one of three types of regression techniques to determine the appropriate mathematical equation: simple linear, multiple linear, or power curve fit. The CERs were individually developed, and were then summarized into either the DOC model or the IOC model. These two models were then combined into the short-haul operating cost model. The DOC model can also be used separately.

Most of the CERs of the short-haul operating cost model are statistical CERs, and all are mathematical as opposed to the other two principal forms of CERs: graphic and tabular. The mathematical form was chosen for the CERs to facilitate anticipated computer programming applications. The pros and cons of the statistical approach to CERs have been extensively discussed (ref. 4), and are summarized below:

CER ADVANTAGES:

- Relatively objective
- Provide consistent and reproducible estimates
- Rapid cost estimation
- Less manhours required to prepare estimates
- Potential predictive accuracy improvements

CER DISADVANTAGES:

- Past practices are reflected in the equations
- Statistics questionable when extrapolating
- Does not eliminate prediction uncertainty
- Tendency to over-simplify

2.1 Direct Operating Cost Model

The short-haul DOC model contains the major aircraft operating cost categories used by the ATA DOC methodology. These categories follow the summary-level CAB Form 41 functional cost categories of schedule P-5.2, Aircraft Operating Expenses:

- Flying Operations
- Direct Maintenance - Flight Equipment
- Depreciation - Flight Equipment

These expense functions, identified with their appropriate account numbers and CAB Form 41 schedules, are shown in Tables 1-4 and 1-6.

Flying operations expense (account 5100), as defined for the DOC model, differs from the CAB Form 41 definition of that element. In the model flight equipment rentals expense (account 5147) is combined with flight equipment depreciation. In the CAB reporting system, flight equipment rentals expense (account 5147) is considered part of flying operations expense. For purposes of the study, it was treated as a capital acquisition expense, and was therefore combined with flight equipment depreciation expense. The four detail functional accounts which make up flying operations are listed in Table 1-5 with their objective accounts as defined by the CAB. The DOC model includes a CER for three flying operations expense elements: flight crew;

fuel and oil and insurance. The category for other flying operations expenses was not modeled because it normally is too small to be significant.

Flight equipment maintenance expense includes the direct maintenance (5200) and the applied maintenance burden (5300) allocated to flight equipment. Flight equipment, as used in the model, is defined as the aircraft plus the spares and parts required to support it. This follows the CAB definition.

Flight equipment depreciation expenses pertain to those of the aircraft and the rotable (or depreciable) spares and spare parts required to support it. Flight equipment expendable parts, as an element of expense, are considered a maintenance expense, according to the CAB, since these parts are not treated as an investment item. For the cost model, all flight equipment was considered purchased and not leased.

Figure 2-1 shows aircraft direct operating cost in terms of dollars per trip versus average stage length (ASL) and is based on CAB 1973 expense and operational data (ref. 5). The aircraft group in the figure formed the data base for the DOC model. They ranged in size from the turboprop DHC-6 to the turbofan B727-200. The parameters are derived from data in CAB Form 41 schedules P-5-2 (aircraft operating expenses), T-2 (revenue aircraft miles), and T-3 (revenue aircraft departures). Figure 2-1 serves several purposes: it identifies the aircraft groups; it depicts the range and orders of magnitude of DOC for each aircraft group; and it shows the trend of dollars per trip versus average stage length. Normally, short-haul stage length is any average stage length $\leq$ 500 statute miles (805 kilometers). This basic definition was a study guideline constraint, however, the data included in Figure 2-1 was not limited to the 500 statute miles for it was necessary to include all B727 data points to more accurately determine the cost trends of that aircraft group.

The methodological approach selected for developing the short-haul DOC model varied with the particular cost element under consideration. For example, flight crew expense could be determined using one of several cost-estimating methods. The statistical approach (or top-down method) was selected as the most effective way to model that particular operating expense. The selection of that approach was heavily influenced by the type of expense and operational data contained in the CAB Form 41 reporting system. Flight equipment direct maintenance expense, on the other hand, was investigated in considerable detail, and included evaluation of several different analytical approaches, since this particular DOC element has received much attention in past years. Thus, considerable care was taken to assure the most effective treatment of that subject as was practicable. The remaining major DOC elements, depreciation, insurance, and fuel, oil and taxes expense were also developed to a degree commensurate with their relative importance to total operating costs. The unique aspects of each CER of the DOC model is discussed in the following section.

2.1.1 Cost-Estimating Relationships. The short-haul DOC model contains 13 cost-estimating relationships (CERs) which encompass the three major DOC elements discussed previously. This part of the short-haul operating cost model requires 18 explanatory (independent) variables to determine the annual DOC of a fleet of transport aircraft. Each of the CERs has a symbol identifier to facilitate its handling within the cost model, and will be discussed in the order of the functional cost elements which contain them (Table 1-4). The entire DOC model will be summarized in Section 2.1.2. However, the mathematical expression describing each CER will also be given at the end of the disucssion of each particular cost element. The 13 CERs of the DOC model are:

- Flight Crew (FCE)
- Fuel, Oil, and Taxes (FOT)
- Insurance (INS)
- Airframe Direct Maintenance - Turbofan (ADMTF)
- Airframe Labor Content - Turbofan (ALCTF)
- Airframe Direct Maintenance - Turboprop (ADMTP)
- Airframe Labor Content - Turboprop (ALCTP)
- Engine Direct Labor - Turbofan (ADLTF)
- Engine Maintenance Materials - Turbofan (EMMTF)
- Engine Direct Maintenance - Turboprop (EDMTP)
- Engine Labor Contents - Turboprop (ELCTP)
- Applied Maintenance Burden (AMB)
- Depreciation - Flight Equipment (DFE)

2.1.1.1 Flight Crew (FCE): This cost element encompasses all wages, salaries, and fringe benefits of personnel associated with the in-flight operation of the aircraft. The six objective accounts comprising flight crew expense are listed in Table 1-5. Flight crew expense, for 1973 operations, comprised 14.2 percent of the total operating expense of the local service airlines (Table 1-8).

The CER for this functional expense is similar in format to the mathematical form of the ATA DOC method. A detailed cost-estimating methodology which considered the quantitative effects of aircraft scheduling, flight crew scheduling, airline route network, etc., could not be effectively developed within this study scope, thus, the flight crew expense CER of the DOC model was based on independent variables similar to the aircraft gross weight parameter of the 1967 ATA method.

The basic CER for flight crew expense was developed as a dollars-per-block hour term and then expanded to an annual airline fleet basis (millions of dollars/year) to match the dimension attached to the other cost model elements. The pertinent cost and operational data from schedules P-5.2, T-2, and T-3 were used to determine dollars/aircraft block hour factors for the calendar year 1973 crew expenses of all aircraft of the data sample. These crew expense factors were similar to the CAB-derived factors of Reference 5. The aircraft of the data base were grouped according to size and capability.

GROUP I	DHC-6, B99A
GROUP II	F-27, FH-227, YS-11, CV-580, CV-600
GROUP III	DC-9-10, DC-9-30, B737-200, BAC-111-200/-400
GROUP IV	B727-100, B727-200

For each aircraft group, a mathematical expression was developed which reflected the determining factors of the current airline flight deck crew contracts. Total crew expense per block hour for 1973 was the dependent variable. Aircraft maximum gross weight, wircraft cruise or peg speed, and number of crew members were the independent variables. Four preliminary equations were developed, one for each aircraft group, and were then combined into a single predictive equation. These equations were of the form

$$z = a_0 + a_1x + a_2y$$

where

z = flight crew expense ($/block hour)

a_0 = constant term

a_1x = crew-size term

a_2y = aircraft gross weight-plus-cruise speed term

The z-term is derived from the cost data noted previously, and represents a weighted average for each aircraft group, based on annual revenue block hours for each aircraft type. The a_1x-term represents the crew-size term, with x = o for the two-crew complements of Groups I, II and III, and x = 1 for the three-crew complement of Group IV. The a_2y-term is the aircraft gross weight-plus-cruise speed term, and is determined with the use of U.S. Customary Units. The aircraft gross weight is maximum takeoff gross weight (TOGW), in thousands-of-pounds. The cruise speed term (VDC), in miles per hour, is synonymous with the important "peg speed" factor used in the pilots' wage schedules. For purposes of this cost model, the term VDC will represent the aircraft design cruise speed at its design cruise altitude. The relationship of aircraft block speed to V_{peg} or V_{cruise} in generalized transport aircraft performance analysis is shown in Figure 2-2 for the BAC-111-400. The interesting points to note are the wide differences between the 530-mph peg or cruise speed of the BAC-111-400 and the range of operational block speeds: 250 to 310 mph at average stage lengths between 150 and 300 miles. The potential impact of this difference in speeds on the crew compensation of short-haul transports could be significant, but would require more extensive analysis than that performed during the study.

The aircraft characteristics (see Appendix C) used for developing the CER represent average data for each aircraft type. These data are then combined into weighted averages for each aircraft group, using annual revenue block hours for each aircraft type. For example, the value of the aircraft gross weight-plus-cruise speed term (TOGW + VDC) for Group I is 240; this was based on the TOGW and VDC factors for the two aircraft comprising that group; the DHC-6-12.5 and 202; the B99A-10.9 and 255. These two pilot-pay determinants

are combined in this cost model since, in the airline contracts studied, they provided identical contributions to the hourly pay scales.

Restating the generalized crew cost equation for each aircraft group:

$$\text{GROUP I:} \quad 65 = a_o + a_1 (0) + a_2 (240) \tag{1a}$$

$$\text{GROUP II:} \quad 100 = a_o + a_1 (0) + a_2 (348) \tag{1b}$$

$$\text{GROUP III:} \quad 144 = a_o + a_1 (0) + a_2 (652) \tag{1c}$$

$$\text{GROUP IV:} \quad 200 = a_o + a_1 (1) + a_2 (763) \tag{1d}$$

Solving these equations for the a_o, a_1, and a_2 values produced the following composite crew cost expression:

$$z = 27.97 + 33.53 x + 0.18 y \tag{1e}$$

Equation (1e) produces a \$/block-hour estimate in 1973 dollars for the short-haul aircraft types which comprise this study's data base. The coefficient of x represents the incremental block-hour cost of adding a third crew member to a two-crew aircraft. The final CER, which estimates the annual flight crew cost, is

$$FCE = \left[27.97 + 33.53(FCF) + 0.18(TOGW + VDC)\right](RABH)\,(FS)(10^{-6}) \tag{1}$$

The terms in equation (1) are defined in Table 2-7. The 10^{-6} term reduces the CER value to millions of dollars, which makes it consistent with the other CERs in the model.

2.1.1.2 Fuel, Oil, and Taxes (FOT): This expense element covers the costs of aircraft fuel and oil, and all texes except those on payroll (Table 1-5). The local service airlines, during 1973, spent 10 cents of every dollar of total operating expense on fuel, oil, and taxes (Table 1-8). The cost of fuel usually comprises some 94-98 percent of this elements' total. This CER is based on three terms: fuel consumption rate (U.S. gallons per aircraft block hour), fuel cost (U.S. dollars per gallon), and a factor to account for the oil and taxes portions of the total expense. This latter factor was derived from an analysis of schedule P-5.2 expense data for all aircraft types in the data base, and is equal to the sum of accounts 5145.1, 5145.2 and 5169 divided by account 5145.1 (the fuel expense). For the aircraft of the data base, the ratio varied from 1.02 to 1.07 over the 1971-73 period; the weighted average factor used in the CER was 1.045. The CER for the fuel, oil, and taxes expense, in millions of dollars/year, is

$$FOT = [(FCR)(C_f)(1.045)]\ (RABH)(FS)(10^{-6}) \qquad (2)$$

The terms in equation (2) are defined in Table 2-7.

The cost of fuel term (C_f) in equation (2) is an important input because the unit cost of jet fuel has r sen markedly since the latter part of 1973. Figure 2-3 shows the U.S. domestic fuel price trend over the 1970-74 period, with the yearly price range indicated. No attempt will be made to forecast jet fuel prices as this is beyond the scope of the study. For the aircraft types of the model's data base, the average 1973 jet fuel price was \$0.134 per U.S. gallon. The individual aircraft fuel consumptions are listed in the aircraft data tables of Appendix C.

2.1.1.3 Insurance (INS): This element of Flying Operations expense covers insurance purchased; provisions for self-insurance; and injuries, loss, and damage (Table 1-5). Normally, insurance expense is an annual expense for an airline. In 1973, it constituted 0.8 percent of the total operating expenses of the local service airlines (Table 1-8).

The CER for insurance expense can be expressed as

$$INS = [(C_t)(IR)] \; (FS) \; (10^{-6}) \tag{3}$$

The terms of equation (3) are aircraft unit cost (C_t), insurance rate (IR), and fleet size (FS). The insurance rate factor (IR) was determined from the CAB Form 41 schedules which list aircraft prices and annual insurance expense per aircraft type. The CAB Form 41 schedules B-7 and B-43 in the Douglas microfilm library were used to determine the total unit aircraft price (i.e., airline book cost) of certain aircraft purchased by the regional airlines, since the individual components of airframe, engines, and avionics are itemized in these schedules. Pertinent aircraft prices are listed in Appendix C. The annual insurance expense was obtained from schedule P-5.2. A six-year history of insurance rates for two regional airlines for their individual aircraft types is shown in Table 2-1. The pronounced decline in Ozark insurance rates resulted from a strike during part of 1973 which curtailed flight operations for a period of time and which permitted a lower insurance rate to be applied, as representative of possessed but non-operating aircraft. From this six-year data base, the average value of 1.5 percent was selected as the value for IR to be used in developing the CER. As a reference, the 1967 ATA method used 2 percent as an insurance rate, based on turbine transport experience up to that time. Values other than 1.5 percent can be substituted into the model CER if so required for the analysis being conducted.

2.1.1.4 Airframe Direct Maintenance-Turbofan (ADMTF): The eight direct maintenance CERs of the short-haul DOC model are described next, beginning with airframe direct maintenance of turbofan transports (this section) and ending with the CER for the direct labor content of the total direct maintenance cost of turboprop engines (Section 2.1.1.11). The background and rationale behind the analytical approaches selected to develop these eight CERs are discussed in Appendix C.

The airframe maintenance costs for the three-year period, 1971-1973, for each of the four turbofan transport types (DC-9, BAC-111, B737, B727), were analyzed using both the regional airline and domestic trunk data which pertained to these aircraft. The airframe labor and material cost trends are shown in Figures 2-4 and 2-5, and include turboprop airframe data for comparison and trend purposes. These latter data will be referred to in Sections 2.1.1.6 and 2.1.1.7 which discuss turboprop airframe direct maintenance. The turbofan aircraft shown in Figures 2-4 and 2-5 have been grouped into two categories for evaluation: 2-engined aircraft and 3-engined aircraft. The labor and material costs shown in these figures were developed from the CAB Form 41, schedule P-5.2 data of the study data base (Appendix B), and are normalized to 1973 dollars. Outside repair expenses (i.e., maintenance and repair contracted to another company or airline) were converted to airline internal expenses using the generalized approach discussed in Appendix C. An airplane flight is synonymous with an airplane departure or cycle. A simple linear regression fitted to the turbofan airframe maintenance labor cost data of Figure 2-4 gives a negative intercept, which infers a negative maintenance labor cost per flight. This is quite illogical and obviously not indicative of actuality. The turbofan airframe maintenance materials cost

data plotted in Figure 2-5 shows considerable scatter, and no definite trend could be ascertained, particularly between aircraft types. Therefore, a CER development utilizing cyclic and flight hour variables, which would be similar to that of the 1967 ATA DOC method, was discarded in favor of a more generalized approach.

The DOC model CER for turbofan airframe maintenance expense covered all direct labor, materials and outside repair expenses, and was based on a single independent variable - airframe weight (manufacturer's weight empty less total engine dry weight). The dependent variable will be 1973 dollars per revenue block hour. The graphic presentation of the CER for turbofan airframe maintenance cost is shown in Figure 2-6, together with turboprop airframe maintenance cost which will be discussed, and its CER presented, in Section 2.1.1.6. The turbofan and turboprop labor cost lines identified in Figure 2-6 will be discussed in Sections 2.1.1.5 and 2.1.1.7, respectively. The plot points for each aircraft type is taken from Table C-17 of Appendix C, and represents a weighted average, using revenue aircraft block hours, of three years of actual airline maintenance expenses. The turbofan airframe CER is based on the DC-9-10, DC-9-30, B727-100 and B727-200. The BAC-111-200/-400 and the B737-200 were also analyzed, but, because of the small sample size, were not considered in forming the trend-line. The turbofan (and turboprop) cost lines shown in Figure 2-6 are visually-fitted lines. The equation which describes the turbofan airframe direct maintenance cost line mathematically is

$$\$/RABH = 2.8 (W_a)^{.256} \qquad (4a)$$

where RABH is revenue aircraft block hours per year per aircraft and W_a is airframe weight in pounds. The CER for annual airframe direct maintenance cost for a fleet of turbofan aircraft, based on equation (4a) is

$$ADMTF = [\,2.8\,(W_a)^{.256}\,]\;(RABH)\;(FS)\;(10^{-6}) \qquad (4)$$

2.1.1.5 Airframe Labor Content-Turbofan (ALCTF): This cost element was included in the short-haul DOC model only to provide a basis for estimating applied maintenance burden (Section 2.1.1.12). It is not used to calculate the total direct maintenance expense of turbofan airframes. Labor content refers to all direct labor expenses contained within flight equipment direct maintenance expense. The CER for this cost element was determined by visually fitting a line to the adjusted turbofan labor costs (Table C 17 of Appendix C). The labor only line in Figure 2-6, for turbofans, represents that line. The actual data points were not plotted so as to retain clarity of presentation. The mathematical equation for the labor only line is

$$\$/RABH = 0.14\,(W_a)^{.481} \qquad (5a)$$

The CER for annual airframe direct maintenance labor content turbofan is

$$ALCTF = [\,0.14\,(W_a)^{.481}\,]\,(RABH)(FS)(10^{-6}) \qquad (5)$$

2.1.1.6 Airframe Direct Maintenance-Turboprop (ADMTP): The turboprop aircraft which formed the data base were contemporary aircraft ranging in size from the B-99A/DHC-6 (15-19 seats) to the YS-11A (60 seats). The Convair aircraft (CV-580/CV-600) were originally piston-engined and subsequently converted to turborprops. The approach to the turboprop airframe CERs paralleled that used to develop the turbofan airframe CERs. As was the case with the turbofans, the results developed from analysis of CAB Form 41 data for the three-year period did not validate the 1967 ATA cyclic-hourly cost concept. The calculated weighted average airframe direct labor and material costs for the turboprop airframes of the study data base are shown in Figures 2-4 and 2-5.

The CER for turboprop airframe direct maintenance cost, labor and materials, was developed from CAB Form 41 data and is based on the cost data tabulated in Table C-17 of Appendix C. These data points are shown in Figure 2-6. The parametric approach to this CER was identical to that used for turbofan airframe maintenance, and used airframe weight as the single, independent variable. A visually-fitted line through the seven turboprop data points was represented by the following mathematical expression

$$\$/RABH = 1.2 (W_a)^{.358} \qquad (6a)$$

The terms are similar to those of equation (4a). Expanding equation (6a) into an annual-expense CER produces the following estimates for turboprop airframe direct maintenance

$$ADMTP = [\ 1.2 (W_a)^{.358}\ ] (RABH) (FS) (10^{-6}) \qquad (6)$$

2.1.1.7 Airframe Labor Content-Turboprop (ALCTP): This cost element, like that of its turbofan counterpart, was included in the short-haul DOC model only to provide a basis for estimating applied maintenance burden. It is not used in the calculation of total direct maintenance expense of turboprop airframes. The visually-fitted labor only line in the left half of Figure 2-6 represents the CER graphically. The data points were from TAble C-17 of Appendix C and were excluded from the plot. The mathematical expression for the labor-only line is

$$\$/RABH = 0.66 (W_a)^{.371} \qquad (7a)$$

When converted to an annual expense using block hous and fleet size, the CER for airframe direct maintenance labor content-turboprop is

$$ALCTP = [\ 0.66 (W_a)^{.371}\ ] (RABH) (FS) (10^{-6}) \qquad (7)$$

2.1.1.8 Engine Direct Labor-Turbofan (EDLTF): The turbofans which formed the short-haul engine data base are quite close in size and performance. The DC-9, B737 and B727 are all powered by JT8D engines. The JT8D-1 and -7 are takeoff rated at 14,000 pounds (62.3 kN) sea level static thrust, and the JT8D-9 is rated at 14,500 pounds (64.5 kN). The BAC-111 series are Rolls-Royce Spey powered, with the Mk. 506-14W rated at 10,410 pounds (46.3 kN) in the -200 series, and the Mk. 511-14W at 11,400 pounds (50.7 kN) in the -400 series. The CERs for engine direct labor and for engine maintenance materials (Section 2.1.1.9) were developed individually, and were based primarily on the JT8D engine data since that engine flew over 95 percent of all turbofan engine-hours over the three-year time period studied. The two turbofan maintenance CERs must be added together to get total turbofan engine direct maintenance cost.

The cost trend analysis conducted prior to developing these two CERs is discussed in Appendix C. These cost trends did not substantiate the turbofan engine maintenance cost-estimating methods used by the 1967 ATA DOC formulas, and thus the short-haul turbofan engine CERs represent a generalized approach based on engine design, engine unit cost, and aircraft operational variables.

The CER for turbofan engine maintenance labor cost was developed from CAB Form 41 operating cost and payroll data for two airlines, Eastern Air Lines and United Airlines. These two airlines were selected as the basis for this CER because each operated several types of short-haul aircraft powered by JT8D engines, and the range of average stage lengths, in terms of flight time per flight (departure), was wide enough to provide a good basis for trend analysis and curve-fitting. The JT8D engine maintenance labor data

points and the line fitted to them by simple linear regression are shown in Figure 2-7. The mathematical equation for the regression line is

$$MMH/E\text{-}F = 0.36 + 0.75\ (t_f) \tag{8a}$$

where MMH/E-F is maintenance man-hours per engine flight (engine-departure) and t_f is flight time per flight. Also shown in Figure 2.7 is a line derived from the 1967 ATA turbofan engine maintenance labor formula (Ref. 1), using as a basis the JT8D-1/-7 thrust rating of 14,000 pounds (62.3 kN). It appears that the 1967 ATA method, which is based on long-haul domestic trunk operations, tends to overstate engine maintenance labor cost when compared to short-haul operations of the same trunks. However, it should be understood that the 1967 ATA engine labor cost equation, as exemplified by the upper line of Figure 2-7, was based on limited JT8D operating experience, since that engine type did not begin airline operations until February, 1964.

To determine the maintenance labor dollar costs for turbofan engines, an average airline maintenance labor rate for 1973 of $7.21 per man-hours was used to convert equation (8a) to dollar costs. This average labor cost represents an airline average for the short-haul study data base and was derived from CAB Form 41, schedule P-10 data. Table D-1 of Appendix D details the development of these maintenance labor cost rates. Based on $7.21 per MMH, equation (8a) becomes

$$\$/\text{engine-flight} = 2.61 + 5.41\ (t_f) \tag{8b}$$

This equation is based on a single thrust rating, 14,000 pounds (62.3 kN), indicative of the JT8D-1/-7 turbofans. To provide a CER which is sensitive to engine size, a scalar modifier was developed, using engine manufacturers'

warranty data (Ref. 6) for contemporary turbofan engines, which provided a labor cost variation with engine thrust. This thrust adjustment factor was indexed to \$1.00 for the JT8D-1/-7 engine. Adding this factor to equation (8b) and expanding it to an annual engine direct labor cost equation resulted in the final CER

$$EDLTF = [2.61 + 5.41(FTPF)] \, [0.15 \, TSLS^{.196}] \, (N_e)(AFPY)(FS)(10^{-6}) \qquad (8)$$

The first bracket in equation (8) is equation (8b), with the notation for flight time per flight changed to FTPF from t_f for model-handling purposes. The second bracket contains the thrust adjustment factor, with sea-level-static thrust per engine indicated as TSLS. The product of the two bracketed terms determines the turbofan engine direct maintenance labor cost per flight for a given engine. The other terms in the CER: number of engines per aircraft (N_e), number of aircraft flights per year (AFPY), fleet size (FS), and (10^{-6}), are required to produce the final CER dimension in millions of 1973 dollars per year.

2.1.1.9 Engine Maintenance Materials-Turbofan (EMMTF): As developed for the short-haul operating cost model, the maintenance materials cost for a turbofan engine must be determined and then added to the direct labor cost of that engine to estimate the total turbofan direct maintenance cost. Engine maintenance materials, as an operating expense (account 5146.2) in the CAB Form 41 system, includes all costs of materials and supplies consumed directly in the maintenance of aircraft engines and spare parts related to aircraft engines. Included in this expense are engine-related expendable parts, which are those parts consumed on a recurring basis.

As with the turbofan maintenance labor costs discussed in the preceding section, the three-year-average maintenance materials cost for the short-haul, JT8D-powered transports exhibited considerable scatter, as shown in Figure 2-8. The costs which were plotted are on a per-engine, per-flight basis, with flight time per flight used as the independent variable. The cost data shown represents all internal airline expense, as all outside repair costs were restated as airline internal costs using the generalized approach described in Appendix C. The correlation line shown in Figure 2-8 was visually-fitted. The mathematical expression for that line is

$$\text{\$/engine-flight} = 4.67 + 6.67\ (\text{FTPF}) \tag{9a}$$

Equation (9a) is based on only one engine, the JT8D, and had to be restructured to provide a more flexible cost-estimating equation for conceptual transport evaluation. This was done by revising it to reflect changes in engine unit cost and in engine thrust. D viding the right-hand side of equation (9a) by 0.443, and adding a thrust adjustment factor similar to that used in equation (8), resulted in the following expression:

$$\text{\$/engine-flight} = \left[10.54\left(\frac{C_e}{10^6}\right) + 15.06\left(\frac{C_e}{10^6}\right)(\text{FTPF})\right]\left[0.3\ \text{TSLS}^{.126}\right] \tag{9b}$$

The value, 0.443, represents the 1973 unit price of a JT8D in millions of dollars per engine, and was obtained from analysis of CAB Form 41 schedules B-7 and B-43. The thrust adjustment factor in the second bracket is based on sea-level-static thrust (TSLS) per engine (in pounds), and was developed by correlating the unit price and engine thrust data of contemporary turbofans of approximately the same design era. The engine types considered were the Rolls-Royce Spey, the JT8D, and the JT3D. The resultant factor was indexed

to 1.00 for the 14,000 pound (62.3 kN) JT8D-1/-7 engine. Expanding equation (9b) to derive an annual turbofan engine maintenance materials cost resulted in

$$\text{EMMTF} = \left[10.54\left(\frac{C_e}{10^6}\right) + 15.06\left(\frac{C_e}{10^6}\right)(\text{FTPF})\right] \cdot x$$

$$\left[0.3\ \text{TSLS}^{.126}\right]\ (N_e)\ \ (\text{AFPY})\ (\text{FS})\ (10^{-6}) \qquad (9)$$

The format and terminology are similar to those used in equation (8), the turbofan direct labor CER.

The 1967 ATA DOC method also used unit engine cost and flight time per flight to determine turbofan engine maintenance materials cost. However, it is somewhat difficult to compare the results of that method with the actual expenses being incurred in today's airline operations. This difficulty is exemplified by the cost comparison shown in Figure 2-9. United Airlines actual costs based on 1971-73 operations are compared with predicted costs using the 1967 ATA formula with two typical engine prices. The UAL cost data was also converted to 1967 dollars to match the ATA base year of 1967. From this comparison, it would appear, (provided UAL data is considered typical), that the 1967 ATA formula for engine maintenance materials cost overstates that element of cost just as it overstated engine maintenance labor cost. Thus, equation (8) and (9), which are based on recent actual cost data, would be more representative of short-haul aircraft operations.

2.1.1.10 Engine Direct Maintenance-Turboprop (EDMTP): The turboprop engine data base used for this study provided a more expansive sample in terms of engine size than did that of the turbofan. The turboprop engines which were

studied ranged in size from the 715-ESHP (equivalent shaft-horsepower) PT6A-27, which is installed in the B-99 and the DCH-6 aircraft, to the 3,750-ESHP Allison 501-D13, which powers the CV-580 aircraft. However, the lack of discernible maintenance cost trends for these engines, based on analysis of CAB Form 41 data, prevented the development of individual CER's for direct labor and for maintenance materials as was done for the turbofan engines. Therefore, an analytical approach, similar to that used to develop the airframe maintenance CERs for the model, was selected to develop the turboprop maintenance CER.

The results of the turboprop engine maintenance cost analysis are summarized graphically in Figure 2-10. The six aircraft types are identified at their per-engine ESHP ratings. The cost data points are in terms of dollars per Revenue Engine Block Hour ($/REBH), and have been adjusted for all-internal airline maintenance. The data reflect 1971-73 operations and are in 1973 dollars. Fitting a simple linear regression to the six data points resulted in the total maintenance cost (labor and materials) versus ESHP line shown in the figure. The mathematical expression for this line is

$$\$/\text{REBH} = 2.863 + \frac{3.037}{10^3}(\text{ESHP}) \tag{10a}$$

Expanding equation (10a) to an annual cost basis produced the turboprop engine direct maintenance CER.

$$\text{EDMTP} = \left[2.863 + \frac{3.037}{10^3}(\text{ESHP})\right](N_e)(\text{RABH})(\text{FS})(10^{-6}) \tag{10}$$

2.1.1.11 Engine Labor Content-Turboprop (ELCTP): The turboprop engine total maintenance CER developed in the preceding section was a generalized expression for total engine direct maintenance. This CER was not intended to be separated into its direct labor and maintenance materials components. Because the cost effective method for estimating applied maintenance burden was based on direct maintenance labor dollars instead of total maintenance dollars, the direct labor cost content of the total turboprop engine maintenance cost was required. Based on data from Table C-17 of Appendix C, a labor content (or labor only) CER was developed which followed the same format as that of the total maintenance CER. This CER is shown graphically as the dashed line in Figure 2-10. The actual data points were omitted for clarity of presentation. The mathematical expression for that line is

$$\$/REBH = 2.037 + \frac{1.357}{10^3}(ESHP) \qquad (11a)$$

This hourly cost, when expanded to an annual basis, becomes the turboprop labor content CER.

$$ELCTP = \left[2.037 + \frac{1.357}{10^3}(ESHP)\right](N_e)(RABH)(FS)(10^{-6}) \qquad (11)$$

The CER identified by equation (11) is only used to determine applied maintenance burden for turboprop-powered aircraft. It is not used to determine the total aircraft direct maintenance cost.

2.1.1.12 Applied Maintenance Burden (AMB): Maintenance burden expense is the indirect or overhead cost attached to direct maintenance cost, and pertains both to flight equipment and to general ground property. Each airline allocates this total maintenance expense, reported as functional account 5300 in CAB

Form 41 schedule P-6, between flight equipment (account 5376.6) and general ground property (account 5379.8). Table A-6 of Appendix A details the objective accounts comprising Maintenance Burden expense. The maintenance burden allocated to flight equipment, shown as account 5279.6 in schedule P-5.2 (see Table A-4 of Appendix A), is further allocated by each airline to the various aircraft types within its fleet. In 1973, flight equipment maintenance burden comprised 5.6 percent of the total operating expense of the local service airlines.

Applied maintenance burden for flight equipment was evaluated in two ways: (1) based on direct mantenance labor cost (the 1967 ATA DOC approach), and (2) based on the total flight equipment direct maintenance cost. As a result of an analysis of the entire aircraft-airline data set used in the short-haul study, the former method was selected because it was a more consistent predictor. Tables 2-2 and 2-3 list the applied maintenance burden-to-direct labor ratios (AMB/DL) for the regional airlines and for the domestic trunk aircraft, respectively. The regional airline ratios shown in Table 2-2 account for all aircraft types within each airline's fleet, and are not always identical for each aircraft type within that fleet. As an example, the three types of aircraft in the Frontier Airlines Fleet, the B737-200, the CV-580, and the DHC-6, in 1973 each had an AMB/DL ratio of 1.55. For that same year, North Central Airlines, however, had different ratios for each of its two aircraft types; for example, the ratio for its DC-9-30s was 2.77, while that for its CV-580s was 1.96. Four of the eight local service airlines, in 1973, had identical AMB/DL ratios for each of its aircraft types; the other four did not. This variance, among the local service airlines, in the method by which each allocates its maintenance burden expenses could not be explained from the

data, and did not suggest a detailed modeling approach to this CER. The domestic trunk airlines, by comparison, exhibit a more uniform internal pattern for the AMB/DL ratio. For the 1971-73 period studied, only Continental and Western (for 1973) showed large differences in the ratio between short-haul aircraft types.

The applied maintenance burden CER for the short-haul operating cost model was based on the AMB/DL ratio determined from the air carrier average ratios for 1973, and on the total direct aircraft maintenance labor as computed in the model for turbofan and/or turboprop aircraft, depending on which is being evaluated. In equation form, this CER is

$$\text{AMB} = 1.88\,[(\text{airframe direct labor cost}) + (\text{engine direct labor cost})] \qquad (12)$$

The AMB/DL ratio of 1.88 represents the 1973 average for all short-haul aircraft types operated by both regional and domestic trunk airlines. This ratio represents the arithmetic means for the 1973 ratios. For either the turbofan or turboprop aircraft under study, the direct maintenance labor cost for the airframe and the engines must be determined, using either equations (5) and (8) for the turbofan or equations (7) and (11) for the turboprop. This total maintenance labor cost times the AMB/DL ratio determines the flight equipment applied maintenance burden cost.

2.1.1.13 Depreciation - Flight Equipment (DFE): This expense category, represented by functional account 7075.6, includes all charges to operating expenses for depreciation of flight equipment. All losses suffered through current exhaustion of the serviceability of flight equipment, due to wear and tear from use and the action of time and the elements, which are not replaced

by current repairs are recorded in this account. Flight equipment, as defined in the CAB accounting guidelines, includes the complete aircraft as well as the rotable parts and assemblies related to it. The CAB functional accounts comprising flight equipment depreciation expense are detailed in Table A-14 of Appendix A. Cross reference is made to the balance sheet accounts for operating property and equipment since some of the CAB Form 41 data used for the analysis was extracted from CAB Form 41 Balance Sheet schedules B-1, B-5, B-7, B-8, B-9, B-14 and B-43.

Air carriers also recognize losses in the serviceability of flight equipment expendable parts caused by obsolescense and deterioration. The provisions for this expense are recorded in functional account 7073.1 of schedule P-5.2. While not a depreciation expense as defined by the 7075-series of accounts, it is usually considered together with flight equipment depreciation expense for purposes of analysis. However, an examination of the regional airline expenses in this account, for 1971, 1972 and 1973, determined that that particular expense comprised a very small percentage of total operating expense (averaging about 0.1% TOE), and exhibited irregular trends among the airlines studied. It was therefore concluded that exclusion of this operating expense element from the short-haul DOC model would not affect the model's usability.

The total annual expense of flight equipment acquisition, as considered in the model, includes the annual operating expense of rentals (account 5147 of schedule P-5.2) as well as that of depreciation. In 1973, the local service carriers spent 8.8¢ of every operating dollar on these functions, with about 45 percent of that total spent for rentals. The rentals percentage for the group of air carriers which form the short-haul cost model data base varies considerably, depending on the financial environment in which

each operates. For example, in 1973, Piedmont's rentals percentage was 5 percent, with only one aircraft of their 45-aircraft fleet leased. On the other hand, Aloha's rentals percentage was 90 percent, with five of their seven operating aircraft leased. The short-haul aircraft of the domestic trunks exhibit this same variation, as shown in Table 2-4. For purposes of the cost model, all flight equipment, including spares, spare parts and assemblies, will be assumed to be purchased. The elements considered in the analytic approach to develop the CER for this operating expense element is presented in Table 2-5.

The annual depreciation expense of flight equipment is determined by the total cost of the equipment, and by its service life and residual value. The airlines usually depreciate flight equipment using the straight-line method (ref. 7), and normally consider service lives ranging from 10 to 16 years and residual values ranging from 5 to 15 percent of initial cost in determining their annual depreciation expense. In certain cases, the airlines will use a fixed calendar date to indicate the end of service life (e.g., June, 1979), and a fixed cost (e.g., $100,000 for an airframe) instead of a percentage of initial cost as the residual value. Tables C-22 and C-23 of Appendix C detail these data for the aircraft-airline combinations used for the study data base. The depreciation schedules used by the airlines for flight equipment usually differ from those used by the CAB for rate-making purposes. In the latter method, each transport type is assigned a certain service life and a residual value in terms of years and percent of original cost, respectively. For the short-haul aircraft types studied, these criteria were as follows: 3-engine turbofan - 14 years and 2 percent; 2-engine turbofan - 14 years and 2 percent; 2-engine turboprop - 10 years and 15 percent.

The 1967 ATA DOC method used still another schedule for depreciation of subsonic turbine-engined transports - 12 years to 0 percent residual value.

The depreciation method used for the short-haul DOC model was the straight-line method, with the initial cost of the aircraft and its rotable spares depreciated to a 15 percent residual value over a 12-year service life. These numerical values represent nominal values for all short-haul aircraft types studied, and are appropriate for both turbofan and turboprop aircraft.

In airline depreciation accounting a distinction is made between rotable (or repairable) spares and parts, and expendable spares and parts. Expendable spares and parts are not considered to be a depreciable asset; therefore, they are treated as an annual consumption item and are replenished as required. Rotable spares and parts are usually assigned the same service life and residual value as the flight equipment they pertain to and have the same depreciation schedule. This accounting treatment of rotable spares and parts will be used in the short-haul DOC model. The results of a rotable spares and parts analysis conducted for selected regional airlines is summarized in Table 2-6. The purpose of this analysis was to determine which type of estimating relationship would be incorporated into the model to estimate the unit cost of spares and parts associated with each aircraft. Two methods were evaluated: method I, which was based on a percentage of aircraft unit cost, and method II, which required individual unit costs of the airframe and the engine to determine the initial cost of spares and parts. The latter method is used in the 1967 ATA DOC formula, with the airframe and engine spares and parts percentages in that method included in Table 2-6 for comparison with the percentages derived for the representative short-haul airlines. The term airframe, as used here, includes the propellers (for the turboprop aircraft)

and the communications and navigational equipment. The engines term of method II includes spare engines as well as engine spare parts. As might be expected, there were some significant variations among the airlines in the spares and parts percentages shown in Table 2-6, particularly in the engines category. These variations are the result of factors such as individual airlines spares provisioning policy, type and number of aircraft in the airlines' fleet, engine and airframe reliability, engine and airframe overhaul schedules, and number and type of stations within an airline's route network. Based on the type of data available in the CAB Form 41 reporting system, a detailed analysis of factors such as there were impracticable. The spares and parts percentage for the depreciation CER of the short-haul DOC model was, therefore, based on the total aircraft unit cost (method I) and was determined to be 12 percent, a value considered to be representative of a short-haul airline which flies contemporary transport aircraft.

The depreciation flight equipment CER is summarized as an annual expense in the following equation:

$$DFE = (C_t)(1.12)(1-RV)(1/DP)(FS)(10^{-6}) \tag{13}$$

The aircraft unit cost (C_t) is in 1973 dollars. The depreciable spares and parts factor is 1.12, the residual value (RV) is 15 percent, and the depreciation period (DP) is 12 years. These three model constants can be changed to other values if so required by a particular air transportation analysis.

2.1.2 DOC Model Summary: The short-haul DOC model is comprised of the 13 cost-estimating relationships (CERs) described in Sections 2.1.1.1 through 2.1.1.13. However, not all of these elements are additive in determining the total direct operating cost of a turbofan or turboprop aircraft fleet. Certain

maintenance labor CERs were developed only to estimate applied maintenance burden. The CERs required for determining total direct operating costs are given below for each type of aircraft.

Turbofan

Flight Crew (FCE)	(1)
Fuel, Oil, and Taxes (FOT)	(2)
Insurance (INS)	(3)
Airframe Direct Maintenance (ADMTF)	(4)
Engine Direct Labor (EDLTF)	(8)
Engine Maintenance Materials (EMMTF)	(9)
Applied Maintenance Burden (AMB)	(12)
Depreciation (DFE)	(13)

Turboprop

Flight Crew (FCE)	(1)
Fuel, Oil, and Taxes (FOT)	(2)
Insurance (INS)	(3)
Airframe Direct Maintenance (ADMTP)	(6)
Engine Direct Maintenance (EDMTP)	(10)
Applied Maintenance Burden (AMB)	(12)
Depreciation (DFE)	(13)

The cost elements of the short-haul DOC model are, by study objective, similar to those of the 1967 ATA DOC method, can can be aggregated into the same three main cost categories of flying operations, maintenance, and depreciation when and if required.

The 18 independent variables which are required to operate the DOC model are given, in symbol form, in Table 2-7. The main direct operating cost categories to which each variable pertains are also noted in the table. The definitions and required dimensions of these 18 variables are listed in Table 2-8. The DOC model and its input and output formats were designed using the U.S. Customary Units since the CAB Form 41 data base utilizes these units only, and conversion of the model and the formats into the scientific international system of units would be impractical.

The 13 mathematical expressions comprising the short-haul DOC model are summarized in Table 2-9. The equations retain the numbering system used in the text. Many of the terms in these equations are in narrative rather than in numerical form in order to make them more comprehensivle and to provide a better overview of the model itself.

The output of the short-haul DOC model is in millions of 1973 dollars per year. Each of the 13 CERs has this dimension. Since most of the CERs in the model were developed on a block-hour or on a pre-flight basis, the annual aircraft utilization (RABH) and the number of aircraft flights, or trips, per year (AFPY) are extremely important independent variables. Figure 2-11 depicts the correlation between block time per flight (t_b) and annual aircraft utilization (RABH), based on 1973 operations of the turboprop and turbofan aircraft types used for the study data base. The chart format is identical to that shown in the 1967 ATA method, with the ATA curve for subsonic aircraft shown for comparison purposes. Because of the poor correlation between utilization and block time of the short-haul aircraft studied, it is recommended that the 1967 ATA curve be used to estimate annual aircraft utilization when this input is not otherwise available. The parameters block

C, 2

time (t_b), ground maneuver time (t_{gm}), and flight time (t_f), or FTPF (as it is symbolized in this model) are identical to the 1967 ATA DOC method in their meanings, and are related as follows: $t_b + t_f + t_{gm}$. As used in this model, they refer to the aircraft operational performance at the particular average stage length assumed or determined. In this regard, these parameters represent the average annual performance of a fleet of aircraft over an airline route network.

The output obtained from exercising the DOC model can either be used by itself, or it can be combined with the output of the IOC model, described in Section 2.2, to estimate the total operating cost of a short-haul air transportation system.

2.2 Indirect Operating Cost Model

The short-haul IOC model, by study requirement, was based on the CAB-defined indirect operating cost categories which were shown in the functional alignment depicted in Table 1-6. These expenses have also been classified as servicing, sales, and general expenses in certain CAB analyses (ref. 8), but the more generalized indirect operating expense connotation was used for the study and for the IOC model.

The selection of the cost elements for the IOC model was influenced largely by the CAB Form 41 accounting system. The CAB Form 41 schedules used for the IOC analysis and the process of going from these data to the IOC model were depicted in Table 1-1 and Figure 1-3, respectively. The data base used for the IOC model, as given in Appendix B, did not include every objective cost element of each functional cost account, but contained only those elements which provided the most insight into system-level IOCs. After thorough review

of past IOC methods, six functional cost elements were selected for this study to represent the total IOC of a regional airline. These were:

- Passenger Service Expense (PSE)
- Aircraft and Traffic Servicing Expense (ATSE)
- Promotion and Sales Expense (PASE)
- Ground Property and Equipment Expense (GPEE)
- Amortization Expense (ADPE)
- General and Administrative Expense (GAE)

Passenger service expense was broken down into several components for modeling purposes: (1) cabin attendant expense; (2) food and beverage expense, or beverage only expense, and (3) other passenger service expense. Likewise, aircraft and traffic servicing expense was separated into (1) aircraft control and line servicing expense, (2) aircraft landing fees expense, and (3) traffic servicing expense. These two major expense elements consumed 32 cents of every total operating expense dollar the regional airlines spent in 1973, and thus required a more detailed approach to cost-estimating than did the other indirect operating expense elements. The symbolical representations, noted in parenthesis, of each of the six cost elements were selected to provide ease of handling in the model development process.

The statistical approach was determined to be the most effective approach for modeling the various IOC elements. Commonly used techniques of correlation and regression were selectively applied, once the dependent and independent variables were ascertained, to develop each mathematical CER. The selection of this approach was heavily influenced by the type of cost, traffic, and operational data available from the CAB Form 41 records. It was originally intended to give the IOC model the capability to perform in-depth

parametric and sensitivity analyses, but the nature of the CAB Form 41 data was such that the model design objective was not achieved. However, this does not degrade the cost-estimating capability of the IOC model.

The traffic and operational data contained in the CAB Form 41 traffic schedules (T-1, T-2 and T-3) provided the principal basis for the determination of the independent variables against which the various expense data were correlated. The unit-cost and total-cost trends of the various indirect operating cost categories were evaluated over the 1971-to-1973 time period to assure that the CERs which were developed contained the most appropriate explanatory variable(s). However, each CER was derived from 1973 data only, since the objective of the model was to estimate operating costs in constant 1973 dollars.

A word of caution is appropriate concerning the use of a multi-year analysis to produce airline operating cost estimates. Caves (ref. 9) found that changing relative input prices can block the analysis of time series and that he could find no satisfactory adjustments or deflations to alleviate this problem. Other reputable analysts have also cautioned against using exotic statistical techniques for airline economic analysis (ref. 10 and 11). For example, regarding multiple regression analysis, Caves noted that various difficulties turn out to make this procedure of limited use: (1) the sample size is too small, (2) the number of independent variables determining airline costs is clearly very large, (3) few independent variables are significant at the 5 percent level of confidence, and (4) serious multi-collinearity exists. His suggestion of using simpler but less comprehensive analysis techniques was supported by Cherington (ref. 10) and Wheatcraft (ref. 11). These suggestions (i.e., to use simple regression and scatter diagrams) were found to be very

appropriate for development of the IOC model, and strongly influenced the derivation of each of the CERs. The description and development of each CER which comprises the short-haul IOC model is discussed in the following section.

2.2.1 Cost-Estimating Relationships. The short-haul IOC model contains twelve cost-estimating relationships which encompass the six major IOC elements discussed above. This part of the short-haul operating cost model requires eight explanatory (independent) variables to determine the annual IOC of a fleet of short-haul transport aircraft. Each CER was given a symbolical identifier to facilitate handling during the model development process. The entire IOC model is summarized in Section 2.2.2, where the various ways for grouping these CERs are also discussed. The twelve CERs which comprise the short-haul IOC model are:

- Cabin Attendants (CAE)
- Food and Beverage (FBE)
- Beverage Only (BOE)
- Other Passenger Service (OPSE)
- Aircraft Control and Line Servicing (ACLSE)
- Aircraft Landing Fees (ALFE)
- Traffic Servicing (TSE)
- Promotion and Sales (PASE)
- Ground Property and Equipment (GPEE)
- GPEE Depreciation Content (GPDC)
- Amortization (ADPE)
- General and Administrative (GAE)

Passenger service expense, functional account 5500, includes all expenses chargeable directly to activities contributing to the comfort, safety and convenience of passengers while in flight and when flights are interrupted. It excludes expenses incurred in enplaning or deplaning passengers (included in aircraft and traffic servicing, account 6400), or in securing or selling passenger transportation and caring for passengers prior to entering a flight status (included in promotion and sales, account 6700). The objective accounts comprising passenger service are listed in Table A-7 of Appendix A. During 1973, the regional airlines spent seven cents of every total operating expense dollar on passenger service. In terms of absolute dollars per year for 1973, these expenses ranged from $1.184 million for Aloha, a Hawaiian carrier, to $21.105 million for Allegheny, a local service airline. For modeling purposes, passenger service expenses were separated into three categories: (1) cabin attendant expenses (wages plus fringe benefits), (2) passenger food expense, and (3) other passenger service expense, which includes all expenses not included in (1) and (2). The distribution of passenger service expense among these three categories for the ten regional airlines is shown in Figure 2-12, which is based on 1973 CAB Form 41 data. The two Hawaiian carriers show a low proportion for food expense, about 2%, since their operations are similar in service to those of the intra-state airlines, PSA, Air California and Southwest Airlines. Frontier Airlines shows the highest proportion for food expense (35%). This was the only airline where, in 1973, food expense exceeded cabin attendants expense, but no substantive explanation could be developed from the available CAB Form 41 data. The four CERs for determining passenger service expense are described in Sections 2.2.1.1 through 2.2.1.4.

Aircraft and traffic servicing expense, functional account 6400, includes compensation of ground personnel and other expenses incurred on the ground relating to (1) protection and control of the in-flight movement of aircraft, (2) scheduling and preparing aircraft operational crews for flight assignment, (3) handling and servicing aircraft while in line operation, (4) servicing and handling traffic on the ground, subsequent to the issuance of documents establishing the air carrier's responsibility to provide air transportation, and (5) in-flight expenses of handling and protecting all non-passenger traffic including passenger baggage. This expense comprised about 25% of the regional airlines' total operating expenses for 1973. Because of this fact, this functional expense received considerable analytic attention during the model development process so that the most satisfactory explanatory variables could be determined. Three functional accounts comprise aircraft and traffic servicing in the CAB Form 41 accounting system:

- Aircraft servicing (account 6100)
- Traffic servicing (account 6200)
- Servicing administration (account 6300)

These three functional accounts are detailed in Tables A-8, A-9, and A-10, respectively, of Appendix A. The distribution of aircraft and traffic servicing expenses among these three expense categories is shown in Table 2-10, which was based on analysis of regional airline costs for 1973. Since the CAB does not include Aloha Airlines in the same air carrier category (Group III) as it does the other nine regional airlines studied, Aloha does not have to break down its aircraft and traffic servicing expenses into the three main categories just described. An example of the latitude permitted by the CAB in cost reporting is exemplified by Southern Airways. Although

it should report its aircraft and traffic servicing expenses in the three separate accounts just described, Southern chooses instead to report only aircraft servicing (6100) and traffic servicing (6200) expenses, with servicing administration (6300) apparently included in accounts 6100 and 6200. No substantive explanation could be obtained from the CAB Form 41 cost data as to the manner in which the regional airlines determine servicing administration expense. As a result, the three CERs which were developed to estimate aircraft and traffic servicing expense included this servicing administration expense on a specially allocated basis. These three CERs, which are described in Sections 2.2.1.5 through 2.2.1.7, are (1) aircraft control and line servicing, (2) aircraft landing fees, and (3) traffic servicing.

Some of the traffic and operational characteristics which might influence aircraft and traffic servicing expenses are shown in Table 2-11. One objective of the IOC study was to determine whether certain operating costs could be correlated to these types of variables, both on an individual station basis and a total airline basis. One particular goal of this phase of the analysis was to determine the effect of the volume of station operations on aircraft and traffic servicing expenses. For example, do the large number of passenger enplanements and aircraft departures per station in Hawaiian Air's route system have any inherent cost efficiencies that can be identified from available CAB Form 41 data? Unfortunately, this question could not be answered satisfactorily within the time period and scope of this study. As a result of that finding and the fact that, when reporting CAB Form 41 costs to the CAB, the airlines do not have to list operating expenses on a city-pair basis, the short-haul IOC model developed as part of the study is unable to evaluate the effect on IOC of different route traffic densities.

The development of a practicable IOC model was also limited by the intercorrelation of the various cost-determining parameters. This also limited a study performed by Caves on the domestic trunk airlines (ref. 9). As with his study, the sample size available for this study of short-haul IOCs was also very small, - only ten airlines comprised the IOC data base. Because of this, the use of sophisticated multiple correlation and regression techniques was kept to a minimum during the IOC model development process. These techniques were used only when a single independent variable would not produce a satisfactory CER. An example of this intercorrelation of airline operational variables is shown in Figure 2-13, which depicts the relationships between several explanatory variables selected for cabin attendants expense analysis. Many of the independent variables which might be correlated against operating costs are derived data, not raw data as is the frequent conception. Those items in rectangular block format in Figure 2-13 are actually submitted to the CAB in that form by the airlines; the others must be derived using the factors and relationships indicated. These relationships between cost-determining variables apply to DOC models and analyses as well as to the IOC example just discussed, and must be understood when interpreting these types of costs.

The following sections describe the development of the 12 CERs comprising the short-haul IOC model. Included in each section will be a description of the particular costs being modeled, the process by which the independent variables were selected and screened, and the selection of the preferred equation.

2.2.1.1 Cabin Attendants (CAE): This expense category, as defined for the short-haul IOC model, included all wages of cabin attendant personnel (5524)

(5524) plus a prorated share of personnel fringe benefits, which are reported in three expense categories: 5536 - Personnel Expenses, 5557 - Employee Benefits and Pensions, and 5568 - Payroll taxes. These fringe benefits were prorated using the ratio of cabin attendant wages (5524) to total personnel wages in passenger service, accounts 5521 through 5535. For 1973, this cabin attendant expense comprised from 34 to 56 percent of total passenger service expense for the regional carriers, with the average near 49 percent. The two Hawaiian carriers averaged 68 percent for the same year, but this was because they do not provide the same food and beverage service as the Mainland carriers. Food and beverage expense will be discussed in the next section (2.2.1.2).

Two analytical approaches were considered in modeling this cost element. A detailed, airline-by-airline method which considered factors such as aircraft size and cabin configuration, aircraft scheduling, cabin crew scheduling, and the number of types of stations within an airline's route network might have provided a more accurate estimate than did the more generalized statistical approach which was actually used for this CER. However, this type of model could not be developed from the CAB Form 41 data.

Five independent variables were correlated against annual cabin attendants expense for 1973 to determine this CER:

(1) Revenue Aircraft Block Hours (RABH)
(2) Revenue Aircraft-Seat Block Hours (RASBH)
(3) Revenue Passenger Miles (RPM)
(4) Available Seat-Miles (ASM)
(5) Enplaned Revenue Passengers (ERP)

These operating statistics were either derived or taken directly from the CAB Form 41, schedule T-2 data for each of the regional airlines. Items (1) and

(2) are derived data; items (3), (4) and (5) are reported data. Revenue aircraft block hours (RABH) is derived from total block hours (code Z630), revenue airborne hours (Z610), and total airborne hours (Z650) as follows: RABH = (Z630) (Z610) $\div$ (Z650). Revenue aircraft-seat block hours (RASBH) is the product of average available seats per aircraft and revenue aircraft block hours. It was selected since the number of cabin attendants per aircraft is directly proportional to the number of seats in the cabin. The other three variables were taken directly from schedule T-2; they are identified with the following codes:

Revenue Passenger-Miles (RPM)	Z140
Available Seat-Miles (ASM)	Z320
Enplaned Revenue Passengers (ERP)	Z110

Simple linear regression was used to evaluate these five variables. Two measures of fit were used to select the best variable: Coefficient of determination (r^2) and standard error of estimate (S). The results of this regression analysis are:

		RABH	RASBH	RPM	ASM	ERP
Standard Error of Estimate	($M)	1.037	0.779	0.678	0.695	0.898
Coefficient of Determination	(r^2)	0.897	0.942	0.956	0.954	0.923

Since revenue passenger-miles provided a slightly better correlation than did available seat-miles, it was used to develop the cabin attendants CER. The mathematical expression for annual cabin attendants expense per year is

$$CAE = -0.023 + 3.466 \text{ [RPM]} \tag{14}$$

where RPM is in billions per year. This correlation and the line representing

the CER are depicted in Figure 2-14. The data points representing each of the ten regional airlines are identified. Although Allegheny Airlines, by virtue of its merger with Mohawk Airlines in 1972, appears to be in a class by itself when its traffic and capacity elements are compared to the other nine regional airlines, it, nevertheless, was considered to be a part of that group of air carriers.

2.2.1.2 Food-and-Beverage (FEB): Passenger food expense (account 5551, schedule P-6) includes all costs of food and refreshments served passengers, except those food costs arising from interrupted trips. These expenses are included in account 5563, interrupted trips expense, but since these particular food costs were not identified, they were not modeled.

For the short-haul IOC model, passenger food expense was modeled two ways since the data showed a clear distinction between a food-and-beverage operation typical of the local service airlines (and also the domestic trunks) and a beverage-only service as provided by the Hawaiian carriers. This latter service, similar to the type provided by the intra-state airlines, PSA, Air California and Southwest Airlines, will be discussed further and its CER presented in Section 2.2.1.3.

The annual expenses for passenger food expense (account 5551) were correlated against annual enplaned revenue passengers (Z110) for 1973 as shown in the upper part of Figure 2-15. With the exception of Frontier Airlines, the local service airlines trend was reasonably linear with respect to enplaned revenue passengers (ERP). No substantive explanation for Frontier's higher-than-average cost could be ascertained from the CAB Form 41 data. Perhaps if data. Perhaps if data on cost per meal served and number of flights on which

meals were served were available, a better correlation would result. However, since these data were not available, enplaned revenue passengers was selected as the single independent variable. The CER for food-and-beverage service is expressed mathematically as follows:

$$FBE = 0.831 + 0.35 \ [ERP] \tag{15}$$

where annual food-and-beverage expense is in millions of 1973 dollars and annual enplaned revenue passengers is in millions. This equation has the following statistical evaluation parameters: coefficient of determination (r^2) = 0.758; standard error of estimate (S) = \$0.601 million. The coefficient of determination for this CER did not meet or exceed the 90 percent target value assumed for the IOC model for purposes of eliminating certain independent variables, but it was considered acceptable since the CAB Form 41 expense data for this function was very general and lacked detail. The zero-intercept value of this CER (\$831,000) was relatively large, which would imply a sizeable fixed expense for local service airline food-and-beverage operations, but again the lack of detail in the CAB Form 41 data prevented an in depth study of this cost function.

The food-and-beverage CER, as shown in equation (15), is used when evaluating short-haul air transportation systems which provide food-and-beverage service. When a system concept provides a beverage-only service, the CER described in the following section should be used.

2.2.1.3 Beverage-Only (BOE): This CER was based on only two airlines, Hawaiian Air and Aloha Airlines. This very small sample size did not provide as good a statistical relationship as would be desired, since only a two-point equation could be derived. Since comparable data on Mainland intra-state

carriers was unavailable, the CER was determined from only the two airlines. The correlation of beverage-only expense (account 5551) and enplaned revenue passengers (Z110) is shown in the lower part of Figure 2-15, and was plotted using the same scales that were used to plot food-and-beverage expenses in order to provide a comparison of the two types of service. The mathematical expression for annual beverage-only expense (BOE) is

$$BOE = -0.026 + 0.03 \; [ERP] \tag{16}$$

where beverage-only expense (BOE) is in millions of 1973 dollars per year and annual enplaned revenue passengers (ERP) is in millions. This CER is used in place of the food-and-beverage CER, equation (15), but only when evaluating short-haul air transportation systems which provide beverage-only service.

2.2.1.4 Other Passenger Service (OPSE): This expense category was specially created for the IOC model to account for the remaining expenses in passenger service which were not included in either cabin attendants expenses or food and beverage expenses. This remaining passenger service expense, for 1973, comprised from 21 to 33 percent of the total passenger service expense, with traffic liability insurance (account 5556) being the largest single expense item. However, since no discernible pattern of expense distribution was found to exist among the regional airlines which were studied, "other passenger service expense" was modeled as a whole, as opposed to breaking it down into certain categories.

This expense was correlated against three system-level variables: revenue aircraft-miles (RAM), revenue passenger-miles (RPM), and available seat miles (ASM). Simple linear regression was used to fit a line to these data correlations, with the following statistical results:

		RAM	RPM	ASM
Standard Error of Estimate	(\$M)	0.405	0.368	0.422
Coefficient of Determination	(r^2)	0.924	0.938	0.918

Since revenue passenger-miles (RPM) was slightly better, statistically, it was selected as the single independent variable. The mathematical expression for the CER based on revenue passenger miles is:

$$\text{OPSE} = 0.232 + 1.564 \ [\text{RPM}] \tag{17}$$

where other passenger service expense, OPSE, is in millions of 1973 dollars and annual revenue passenger-miles is in billions. The correlation plot of other passenger service expense against annual revenue passenger miles is shown in Figure 2-16. Although Allegheny Airlines appears to be a different class of air carrier because of the wide difference in its annual RPM when compared to those of the other nine regional airlines, it was nevertheless included in the development of this CER since it is still considered to be a local service airline. The regression line in Figure 2-16 is equation (17) in graphic form.

This concludes the development of the CERs which comprise passenger service expense. They will be summarized, along with the rest of the IOC CERs in Section 2.2.2, IOC Model Summary.

2.2.1.5 Aircraft Control and Line Servicing Expense (ACLSE): Aircraft control expenses (account 6100) were separated into two categories for purposes of the IOC model: (1) aircraft control and line servicing expense, and (2) aircraft landing fees expense. The CER for landing fees is described in the next section. As discussed in Section 2.2.1, the expenses reported in

Servicing Administration (6300) could not be analyzed on any consistent basis because of the nonuniformity in the reporting of these expenses by the regional airlines which formed the data base. As a result, the servicing administration expense was allocated to Aircraft Servicing (6100) and Traffic Servicing (6200) on the basis of the total wages and salaries in each of these two functional accounts. An example, using 1973 Allegheny Airlines data, will illustrate this expense allocation method. The total wages and salaries expense (objective accounts 21 through 35) in Aircraft Servicing (6100) was $8.858 million, or 24 percent of the total of both Aircraft Servicing and Traffic Servicing. Therefore, 24 percent of the Servicing Administration (6300) expense of $1.529 million, or $0.367 Million, was allocated to Aircraft Servicing, resulting in a total of $26.748 million. From this total, the aircraft landing fees expense (account 6144) of $9.158 million was subtracted, leaving a total of $17.59 million. The $17.59 million expense was identified in this short-haul IOC model as aircraft control and line servicing expense. For 1973, for the regional airlines studied, it ranged from $1.034 million (Aloha) to $17.59 million (Allegheny).

On the basis of previous research (ref. 9, 10, and 11) and an operational analysis of the regional airline system of the 1971-73 time period, five explanatory variables were selected for analysis:

(1) Revenue Aircraft Departures (RAD)

(2) Weighted Revenue Aircraft Departures (WRAD)

(3) Number of Line Stations and Types of Stations

(4) Aircraft Fleet Size (FS)

(5) Revenue Aircraft Miles (RAM)

Item (3) was discarded at the outset since the CAB Form 41 data only provided the average total number of line stations per airline per year, and did not break down that total into the various types of stations which usually comprise an airline's network, for example, the number of turnaround stations, through-stop stations, and different types of maintenance stations. By itself the average number of line stations did not provide a good explanation of aircraft control and line servicing expense ($r^2 = 0.364$), and was eliminated from further consideration.

The other four variables were selected on the premise that aircraft control and line servicing expense would be expected to vary with the number of flights, the size of the aircraft involved, and the number of aircraft-miles flown. Revenue aircraft miles (RAM), on an annual fleet basis, provided the best statistical explanation. The results of the analysis, based on 1973 data are:

		RAD	WRAD	FS	RAM
Standard Error of Estimate	($M)	1.614	1.351	1.705	1.326
Coefficient of Determination	(r^2)	0.887	0.921	0.874	0.927

Revenue aircraft departures (RAD) are the airline fleet totals on an annual basis, and were taken directly from CAB Form 41, schedule T-2. Weighted revenue aircraft departures (WRAD) incorporate the effect of aircraft size. The maximum takeoff gross weight (MTOGW) of each aircraft type within an airline's fleet was used as the weighting value. The annual departures per aircraft type for each airline were taken from CAB Form 41, schedule T-3; the weight data was taken from the aircraft characteristics summaries in Appendix C. Average annual aircraft fleet size (FS) per airline was derived from CAB Form 41, schedule T-2 data item Z820, aircraft days assigned to service-

carrier's routes. Revenue aircraft miles (RAM) are the airline fleet totals, and were also taken directly from CAB Form 41, schedule T-2.

Revenue aircraft miles (RAM) provided the best statistical correlation based on the criteria noted above, and was used to derive the CER for aircraft control and line servicing expense (ACLSE).

$$ACLSE = 0.86 + 0.199 \, [RAM] \tag{18}$$

where aircraft control and line servicing expense is in millions of 1973 dollars per year and revenue aircraft miles are in millions per year.

2.2.1.6 Aircraft Landing Fees (ALFE): Aircraft landing fee expense (6144) was treated separately inasmuch as it can usually be related to an aircraft design parameter - either takeoff weight or landing weight. In 1973, for the ten regional airlines studied, this expense ranged from $1.034 million (Aloha) to $17.59 million (Allegheny). In terms of percent of total operating expense (TOE), the figures ranged from 0.7 percent TOE (Hawaiian Air) to 3.0 percent TOE (Allegheny), with 2.2 percent TOE being the group average.

A survey of U.S. airport landing fee data concluded that, while some airports used takeoff weight to determine landing fee rate, the majority used landing weight. As a result, the CER for this expense will be based on landing gross weight. The correlation between landing weight and aircraft landing fees is shown in Figure 2-17. The explanatory variable in the figure is fleet-average maximum landing gross weight, which was determined from the revenue aircraft departures and the maximum landing gross weight of each aircraft type in an airline's fleet. As an example, using U.S. Customary Units only, the weighted fleet-average maximum landing gross weight (ALGW) of 64,600 pounds for North Central Airlines for 1973 was derived from the following data:

Aircraft	RAD (000)	LGW (1000 lb)
DC-9-30	66.4	93.4
CV-580	152.3	52.0
Weighted Fleet Average		69.6

Correlation of landing fees to only an aircraft weight variable was very poor, as indicated by the data scatter in Figure 2-17. In terms of a landing fee rate, the regional airlines varied from 7.3¢/1000 lb (Hawaiian Air) to 32.9¢/1000 lb (Allegheny) for 1973. This wide divergence in average rate is influenced by the number and types of airports in a given airline's route network, but quantitative explanation for this divergence could not be obtained from CAB Form 41 data.

To provide a satisfactory CER for aircraft landing fees, a factor was derived from the product of revenue aircraft departures and aircraft maximum landing gross weight. The correlation of landing fees to this factor is illustrated in Figure 2-18. It should be noted that this correlation was plotted using logarithmic instead of arithmetic scales. The same data which were used to determine the fleet-average maximum landing gross weight were used to derive this factor, except that aircraft departures are in units of thousands per year, and maximum landing gross weight is in thousands of pounds. Using the 1973 North Central data from above as an example, the explanatory variable for that airline for that year would be (66.4 x 93.4) + (152.3 x 52.0), or 14,121. This value, for 1973, for the regional airlines, ranged from 2,862 for Aloha to 27,804 for Allegheny. Revenue aircraft departures (RAD) for any given airline can be broken down into the departures, maximum landing gross weight, and fleet size associated with each aircraft type

comprising that airline's total fleet. This approach was selected to model aircraft landing fees expense. Fitting a power curve to the data points shown in Figure 2-18 produced the aircraft landing fees CER.

$$\text{ALFE} = (0.688 \times 10^{-6}) \left[\left(\frac{\text{ALGW}}{10^3} \right) \left(\frac{\text{ADPY}}{10^3} \right) \right] (\text{FS})^{\;1.6015} \qquad (19)$$

where aircraft landing fees (ALFE) are in millions of 1973 dollars, fleet-average maximum landing gross weight (ALGW) is in thousands of pounds, aircraft departures per year (ADPY) is in thousands, and fleet size (FS) is in number of aircraft. Where only one type of aircraft comprises a fleet, the symbol ALGW would be the maximum landing gross weight of that type. Equation (19) provided an acceptable explanation of landing fees expense since $r^2 = 0.92$.

2.2.1.7 Traffic Servicing (TSE): Traffic servicing (account 6200) includes all expenses incurred while handing revenue traffic (passengers, baggage, mail, express and freight) while on the ground, and also includes the inflight expenses of handling and protecting all nonpassenger traffic including passenger baggage. It is a very labor-intensive expense category, with salaries, wages and fringe benefits comprising from 67 to 80 percent of the regional airlines' total traffic servicing expense for 1973. Baggage handling, for example, is an area most often discussed for increased efficiency of operation, particularly through adaptation of automation. However, the traffic data in the CAB Form 41 T-schedules do not tabulate items such as baggage carried per passenger, either by the piece or in total weight. In the CAB Form 41 data, a standard passenger weight (including all baggage) of 200 pounds (90.7 kg) per passenger is used, and no factual data is presented which separates the baggage weight from the passenger weight. Another shortcoming of the CAB Form 41 data in the P-9.2 schedule is that although the total number of airline employees

per line station is given, the breakout of this total by function is not given; as a result, an in-depth study of traffic servicing was not conducted during the course of the regional airline IOC analysis.

The traffic servicing expense category in the short-haul IOC model includes a proportionate part of the Servicing Administration (account 6300) expense, on the basis of the percentage of total wages, salaries and fringe benefits in account 6200 to those in both account 6100 and account 6200. This effectively distributed all Servicing Administration expenses between aircraft control and line servicing (ACLSE) and traffic servicing (TSE). The annual traffic servicing expenses for 1973 which became the dependent variable for the CER ranged from $4.621 million (Aloha) to $48.196 million (Allegheny). Aloha's traffic servicing expense was estimated based on the expense distributions of Hawaiian Air since it is not required by the CAB to separate its aircraft and traffic servicing expenses into the three major functional groupings.

Nine variables were selected which, individually or in combination, might be correlated to traffic servicing expense:

(1) Enplaned Revenue Passengers (ERP)

(2) Enplaned Revenue Cargo (ERC)

(3) Enplaned Revenue Tons (ERT)

(4) Revenue Ton-Miles (RTM)

(5) Revenue Aircraft Departures (RAD)

(6) Number of Traffic Servicing Personnel (NTSP)

(7) Number and Types of On-Line Airports

(8) Deplaned Revenue Passengers

(9) Deplaned Revenue Cargo

Deplaned passengers and cargo, items (8) and (9), were eliminated from further consideration since the current CAB Form 41 reporting format does not include that data. As with aircraft control and line servicing expense, the total number of line stations did not provide good correlation ($r^2 \leq 0.9$) and was eliminated. The remaining six variables, which were taken directly or derived from the CAB Form 41 T-schedule data for 1973, provided reasonably satisfactory correlations with traffic servicing expense. Revenue aircraft departures (Z510), revenue ton-miles (Z240) and enplaned revenue passengers (Z110) are from schedule T-1. Enplaned revenue cargo and enplaned revenue tons were derived from schedule T-3 data. Enplaned revenue tons includes the weight of the passengers and baggage as well as the revenue cargo. The average number of traffic servicing personnel were derived from the 6226.1, 6226.3 and 6226.4 categories of schedule P-10. The statistical correlations of these variables to annual traffic servicing expense for 1973 resulted in coefficients of determination (r^2) ranging from 0.917 for enplaned revenue tons to 0.972 for revenue ton-miles. Revenue ton-miles also resulted in the lowest standard error of estimate (S = $2.156 million) of the six variables tested.

Although revenue ton-miles individually provided a satisfactory correlation with traffic servicing expense, multiple correlations were also run using the same six variables to determine whether or not the predictive capability of a multiple-variable CER would be significantly better than that of the single-variable CER using only revenue ton-miles (RTM). The combination of revenue ton-miles (RTM) and revenue aircraft departures (RAD) did improve the statistical qualities of the correlation, as shown below.

		RTM	RTM & RAD
Coefficient of Determination		0.972	0.982
Standard Error of Estimate	($M)	2.156	1.826

The multiple correlations were run using the stepwise regression technique. The mathematical expression for the traffic servicing CER is

$$TSE = 1.31 + 0.082 [RTM] + 0.041 [RAD] \tag{20}$$

where traffic servicing expense (TSE) is in millions of 1973 dollars per year, revenue ton-miles (RTM) is in millions per year, and revenue aircraft departures (RAD) is in thousands per year.

This concludes the development of the three CERs which comprise aircraft and traffic servicing expense. They will be summarized, along with the rest of the IOC CERs, in Section 2.2.2, the IOC Model Summary.

2.2.1.8 Promotion and Sales (PASE): Promotion and Sales (account 6700) includes all expenses incurred in creating public preference for an airline and its services, stimulating the development of the air transport market, and promoting the airline or developing air transportation generally (ref. 3). In 1973, this expense ranged from $5.583 million for Aloha to $30.195 million for Allegheny, and constituted about 10 percent of the regional airlines' total operating expenses. All Group III air carriers, which include the local service airlines and Hawaiian Air, are required by the CAB to subdivide this function into Reservations and Sales (6500) and Advertising and Promotion (6600). These two subfunctions are detailed in Tables A-11 and A-12, respectively, of Appendix A. The Reservations and Sales expense is usually the larger of the two; in 1973, it averaged from 79 to 91 percent of each regional airline dollar spent for promotion and sales.

The initial plan for evaluating this expense element was to conduct a station-by-station analysis, within each airline and then as a group, which related the total and various individual accounts within both Reservations and Sales (6500) and Advertising and Publicity (6600) to selected explanatory variables. However, the non-uniformity in data and expense reporting among the ten regional airlines comprising the IOC model data base and the enormous amount of station cost and operational data that had to be correlated and analyzed within a relatively short period of time restricted the analysis of promotion and sales expenses to a system-basis only.

Four explanatory variables were correlated to annual promotion and sales expense:

(1) enplaned revenue passengers (ERP)

(2) passenger revenue (PREV)

(3) total operating revenue, less subsidy (TRLS)

(4) revenue passenger miles (RPM)

Enplaned revenue passengers, statistical element Z110, and revenue passenger miles, Z140, are annual totals from CAB Form 41 schedule T-1. Passenger revenue and total operating revenue, less subsidy, were annual totals from schedule P-1.2, and were compiled for 1973 only. The results of the correlation of these four variables to annual promotion and sales expense for 1973 is shown below.

	ERP	PREV	TRLS	RPM
Standard Error of Estimate ($M)	1.724	1.351	1.391	1.596
Coefficient of Determination (r^2)	0.950	0.969	0.967	0.957

On the basis of this correlation analysis, passenger revenue would have been selected to develop the CER for promotion and sales expense. However, the

study of short-haul aircraft operating economics did not include the revenue and profit (or loss) aspects of airline operations. In addition, certain conceptual air transportation studies may not generate revenue data, as part of their output. For these reasons the CER for promotion and sales expense for the short-haul IOC model was based on both enplaned revenue passengers and revenue passenger miles, since this combination provided as good a predictive quality as did passenger revenue. The mathematical expression for the promotion and sales expense CER is

$$PASE = 1.785 + 1.201 \left[ERP\right] + 4.716 \left[RPM\right] \tag{21}$$

where annual promotion and sales expense (PASE) is in millions of 1973 dollars, annual enplaned revenue passengers (ERP) is in millions, and annual revenue passenger-miles (RPM) is in billions.

2.2.1.9 Ground Property and Equipment (GPEE): This cost category, for purposes of the IOC model, included all expenses incurred for the direct maintenance, applied maintenance burden, and depreciation of ground property and equipment. Ground property and equipment and flight equipment comprise the total operating property and equipment of an airline according to the CAB Form 41 accounting classification system. Ground property and equipment is further subdivided for depreciation accounting purposes: all depreciation expenses relating to maintenance equipment and hangers are recorded in account 7075.8 of CAB Form 41 schedule P-3; the depreciation expenses for general ground property are recorded in account 7075.9 of schedule P-3. General ground property includes items such as passenger service equipment, ramp equipment, surface transport vehicles and equipment, and communication and meteorological equipment. The comparative airline investments in flight equipment and ground property and equipment for six of the regional airlines

studied are shown in Table 2-12. These dollar summaries, taken from balance sheet schedule B-1, indicate a wide variation in the dollar ratio of flight equipment-to-ground equipment. If this ratio had been more consistent among the regional airline group, it could have provided a good basis for determining the ground property and equipment CER.

The total operating expenses for ground property and equipment, for 1973,for the regional airlines studied ranged from $0.340 million for Aloha to $5.582 million for Allegheny. These ground property and equipment expenses for the group as a whole averaged 1.6% of total operating expense, a rather small percentage when compared to the other major DOC and IOC categories. Applied maintenance burden for ground property was originally planned to be handled in the same way as the burden applied to flight equipment direct maintenance, but the inconsistency of the cost data recorded in schedule P-6 for the direct maintenance and applied maintenance burden of ground property precluded the use of this approach. About the only conclusion reached from this data was that, with the notable exception of Hawaiian Air, the regional airlines allocated from four to ten percent of their total maintenance burden to ground property and equipment (Figure 2-19). This would seem reasonable since most of their operating equipment is flight equipment. The depreciation expense was not investigated in detail since the various types of ground property have different service lives and residual values which are not discernible from the CAB Form 41 data studied. In addition, the amount of ground property rented instead of purchased was difficult to determine. These were the underlying reasons for combining the three expense elements for ground property and equipment into a single cost category for purposes of the model.

The independent variable for determining ground property and equipment expense (GPEE) was the sum of flight equipment depreciation (account 7075/6) and flight equipment rentals (account 5147). These two accounts were selected since they represent the total annual operating expense of all flight equipment whether it was purchased or leased. For 1973, for the regional airlines studied, this depreciation and rentals expense ranged from $2.8 million for Aloha to $25.34 million for Allegheny. This combined expense provided a good basis with ground property and equipment expense, and resulted in a coefficient of determination of 0.946 and a standard error of estimate of $0.354 million. The mathematical expression for this CER is

$$GPEE = -0.369 + 0.227 \ [DFE] \tag{22}$$

where ground property and equipment expense, GPEE, and depreciation-flight equipment, DFE, are in millions of 1973 dollars. An assumption within the short-haul operating cost model is that all flight equipment will be purchased and that the total annual depreciation expense of that equipment will provide the basis for estimating ground property and equipment expense.

2.2.1.10 GPEE Depreciation Content (GPDC): This cost element was incorporated into the short-haul IOC model only for the purpose of determining the general and administrative expenses, which will be discussed in Section 2.2.1.12. It is not additive in determining total annual indirect operating expense since it was included in ground property equipment expense. The depreciation content of ground property and equipment expense was developed using the total annual depreciation expenses from accounts 7075.8 and 7075.9 as the dependent variable and the total annual expense for flight equipment depreciation and rentals as the independent variable. This correlation provided acceptable statistical

results (r^2 = 0.909 and S = \$0.203 million). The mathematical expression for this CER is

$$GPDC = -0.244 + 0.099 \ [DFE] \quad (23)$$

The format for this CER is similar to the format of the ground property and equipment expense CER. The depreciation content, GPDC, and the depreciation-flight equipment, DFE, are in millions of 1973 dollars.

2.2.1.11 Amortization (ADPE): Amortization expense is a small proportion of the regional airlines' total operating expense (less than 1 percent on a group-average basis), but it was analyzed and modeled as a separate CER since it does constitute an operating expense in the CAB accounting system. Basically this account includes those types of expenses which an air carrier chooses to capitalize and charge to operating expense over a period of time instead of only for the year when incurred. These expenses are usually developmental and pre-operating expenses, and are recorded in functional account 7074.1 of schedules P 3 and B-10. These expenses are normally those incurred when introducing new aircraft types within an airline's inventory or the expenses incurred in developing new routes, and are normally deferred until these activities began producing revenue. The magnitude of this expense for the regional airlines, for 1973, ranged from \$0.138 million for Hughes Airwest to \$1.729 million for Allegheny. The CER for this cost element was developed using the total annual airline expenses for 1973 of account 7074.1 and the total revenue aircraft miles, RAM, for 1973, for each airline. The resultant mathematical expression for the CER is

$$ADPE = -0.094 + 0.019 \ [RAM] \quad (24)$$

where amortization of developmental and pre-operating expenses, ADPE, is in millions of 1973 dollars, and annual revenue aircraft-miles, RAM, is in millions. Revenue aircraft miles provided the best correlation of the several explanatory variables investigated ($r^2 = 0.757$), and, although it did not exceed the 90 percent criteria for coefficient of determination as set forth for the IOC model development process, it was selected as the single explanatory variable for this CER.

2.2.1.12 General and Administrative (GAE): All expenses of a general corporate nature not applicable to any particular function are included in this cost element. Examples are general financial accounting activities, purchasing activities and representation at law. The listing of all objective accounts contained within this functional account (6800) is given in Table A-13 of Appendix A. General and administrative expenses for 1973, for the ten regional airlines studied, ranged from $2.341 million for Aloha to $15.664 million for Allegheny, and averaged 5.5 percent of total operating expense for the group as a whole.

Previous analyses of airline operating economics indicated that general and administrative expense correlated well with total cash operating expense less general and administrative expense. This approach, with a slight variation, was used to develop the CER for the short-haul IOC model. The variation was to exclude amortization expense from the independent variable as well as the other costs normally excluded from cash operating expense. This adjusted cash operating cost (ACOE) would be determined by subtracting from total operating expense the following: Flight equipment depreciation expense, ground property and equipment depreciation expense, general and administrative expense, and amortization expense. However, when using the operating cost

model, adjusted cash operating expense is determined by summing up the following operating costs:

- o Flying Operations
- o Flight Equipment Maintenance, including Burden
- o Passenger Service
- o Aircraft and Traffic Servicing
- o Promotion and Sales
- o Ground Property Maintenance, including Burden

The CER for general and administrative expense was developed from 1973 regional airline annual operating costs from the CAB Form 41, P-1.2, P-3, and P-7 schedules. The general and administrative expense with adjusted cash operating expense is shown in Figure 2-20, and indicated a reasonably linear trend. The correlation also provided satisfactory statistical results (r^2 = 0.931, S = $1.082 million), and provided the basis for the following mathematical expression for the CER:

$$GAE = 0.916 + 0.054 \ [ACOE] \qquad (25)$$

where general and administrative expense, GAE, and adjusted cash operating expense, ACOE, are in millions of 1973 dollars per year. The straight line in Figure 2-20 is the graphical form of the CER.

2.2.2 IOC Model Summary. The short-haul IOC model is comprised of the twelve cost elements described in Sections 2.2.1.1 through 2.2.1.12, however, not all of these elements are additive in determining annual indirect operating expense. For example, the CERs required to determine the IOC of an airline which provides food-and-beverage service are listed below:

Cabin Attendants (CAE)	(14)
Food-and-Beverage (FBE)	(15)
Other Passenger Service (OPSE)	(17)
Aircraft Control and Line Servicing (ACLSE)	(18)
Aircraft Landing Fees (ALFE)	(19)
Traffic Servicing (TSE)	(20)
Promotion and Sales (PASE)	(21)
Ground Property and Equipment (GPEE)	(22)
Amortization (ADPE)	(24)
General and Administrative (GAE)	(25)

If the airline in question provides only a beverage service, equation (16), beverage-only expense, would be substituted for equation (15). food-and-beverage expense. This level-of-service option is the only such option built into the IOC model and must be selected by the user. The cost elements of the IOC model are, by study objective, similar to those used by the airlines to report their IOCs to the CAB. Passenger service expense is the sum of equations (14), (15) or (16), and (17). Aircraft and traffic servicing expense is the sum of equations (18), (19) and (20).

The eight independent variables which are required to operate the short-haul IOC model are summarized, in symbolical form, in Table 2-13. The cost elements to which they pertain are also noted in the table. The definition of each of the eight variables is given in Table 2-14. The revenue ton-miles parameter is based on revenue passenger-miles in the model since most studies of air transportation systems do not determine revenue ton-miles. The other point to recognize is that the IOC model cannot be used without first using the DOC model, since the cost elements of the DOC model are used to determine certain elements of the IOC model.

The twelve mathematical equations of the short-haul IOC model are summarized, in narrative form, tin Table 2-15. The equations are numbered as they are in the text. All independent variables use U.S. Customary Units since the CAB Form 41 reporting system uses these units. The dimension of each independent variable is also noted in the table; that is, revenue passenger-miles is in billions, enplaned revenue passengers is in millions, etc.. The short-haul IOC model, like its DOC counterpart, produces the annual operating cost, in millions of 1973 dollars, of a typical short-haul airline.

2.3 Total Operating Cost Summary

The short-haul operating cost model described in Sections 2.1 and 2.2 encompasses total operating cost as defined by current airline accounting practices and as reported by the airlines to the CAB in the Form 41 reports. The model is comprised of two sub-models: a short-haul DOC model, described in Section 2.1, which was based on contemporary short-haul aircraft operated by the regional and domestic trunk airlines; and a short-haul IOC model, described in Section 2.2, which was based only on regional airlines. The cost elements comprising the DOC model and the IOC model are summarized in Tables 2-16 and 2-17. Table 2-16 presents the individual cost elements by title, while Table 2-17 shows the symbols used to describe each cost element in the model. The titles and symbols shown in these two tables are identical to those used in the sections which describe the development of each CER.

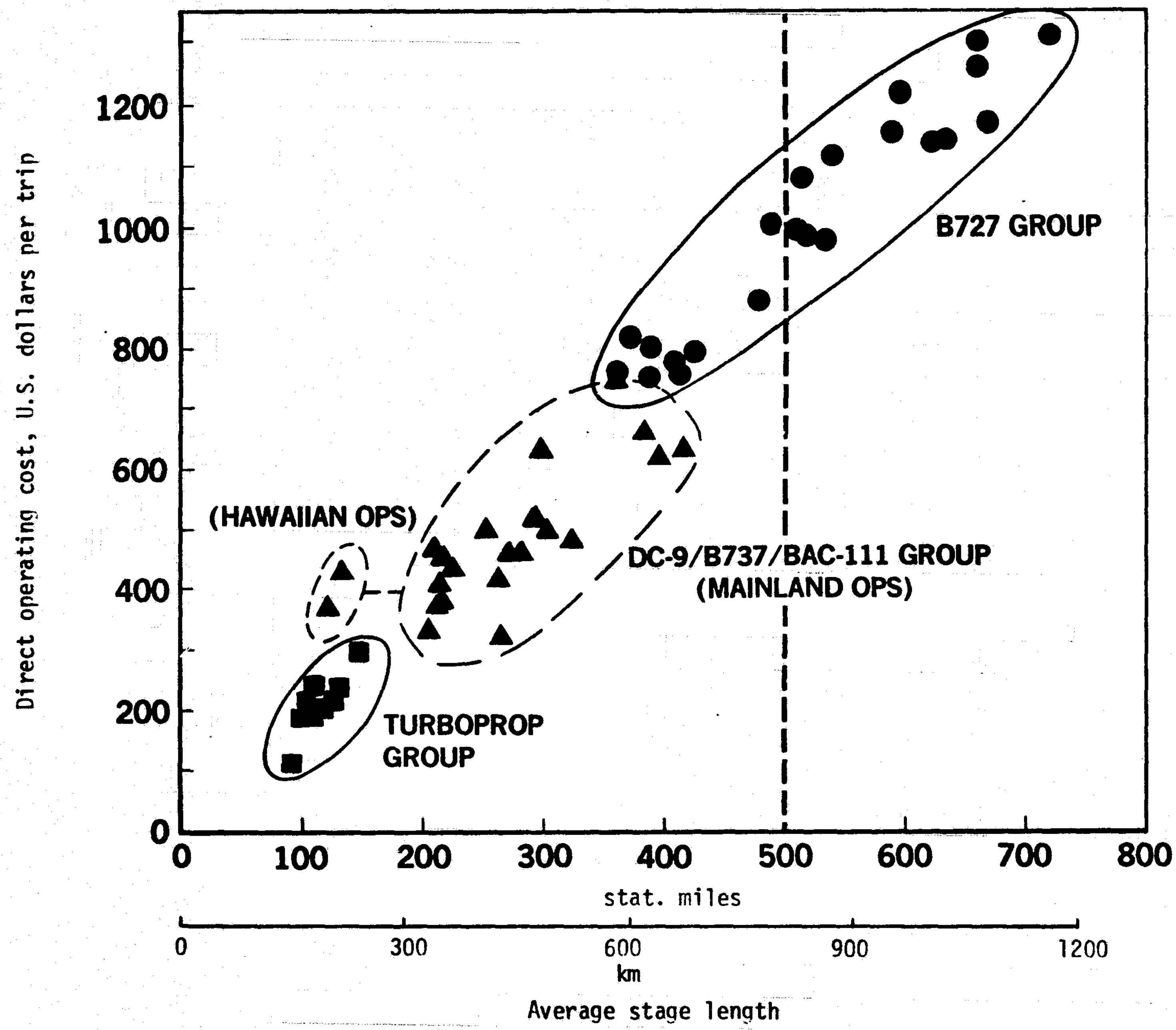

Figure 2-1 - Direct operating cost versus average stage length, 1973 operations

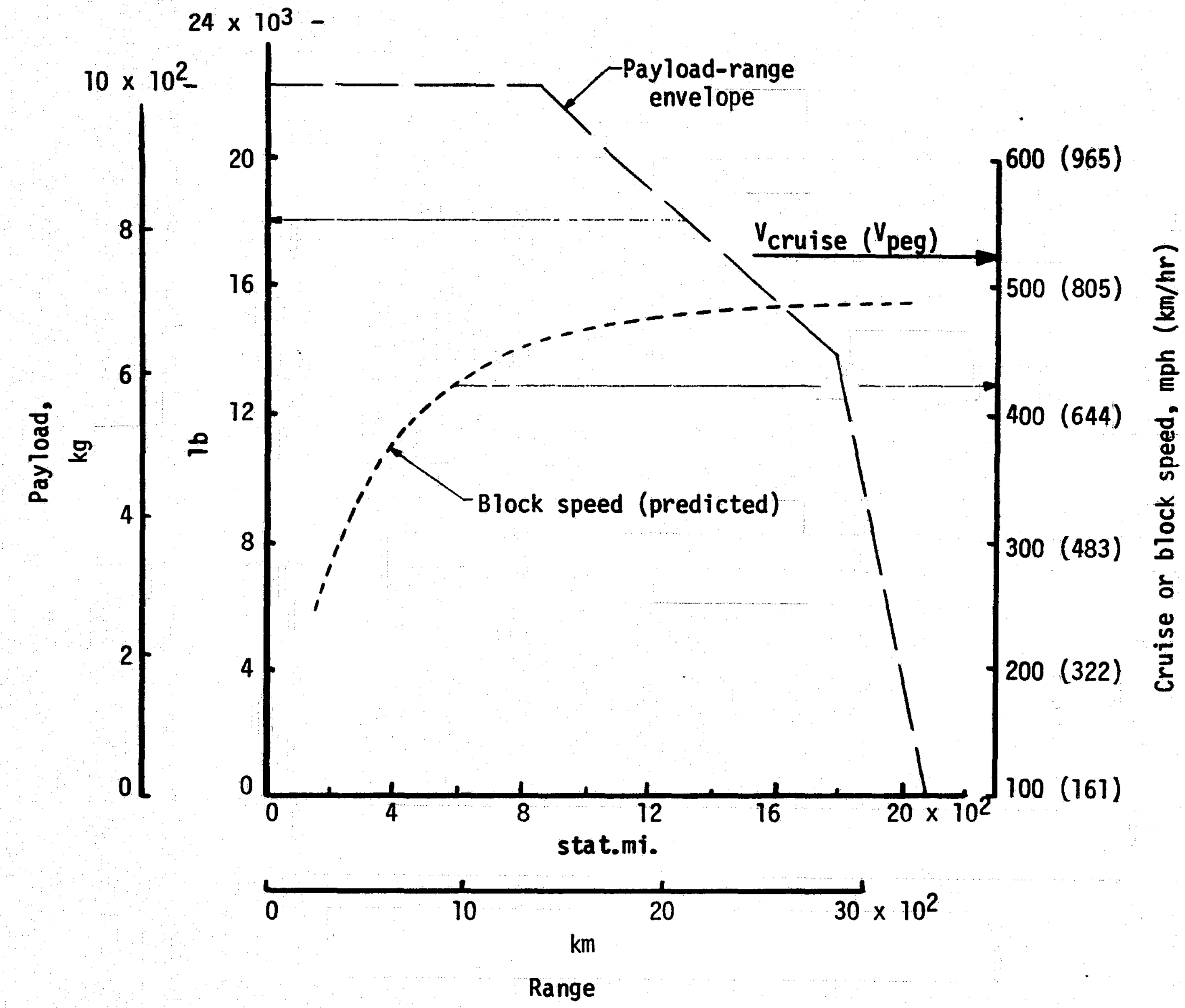

Figure 2-2. - BAC-111-400 speed and payload performance

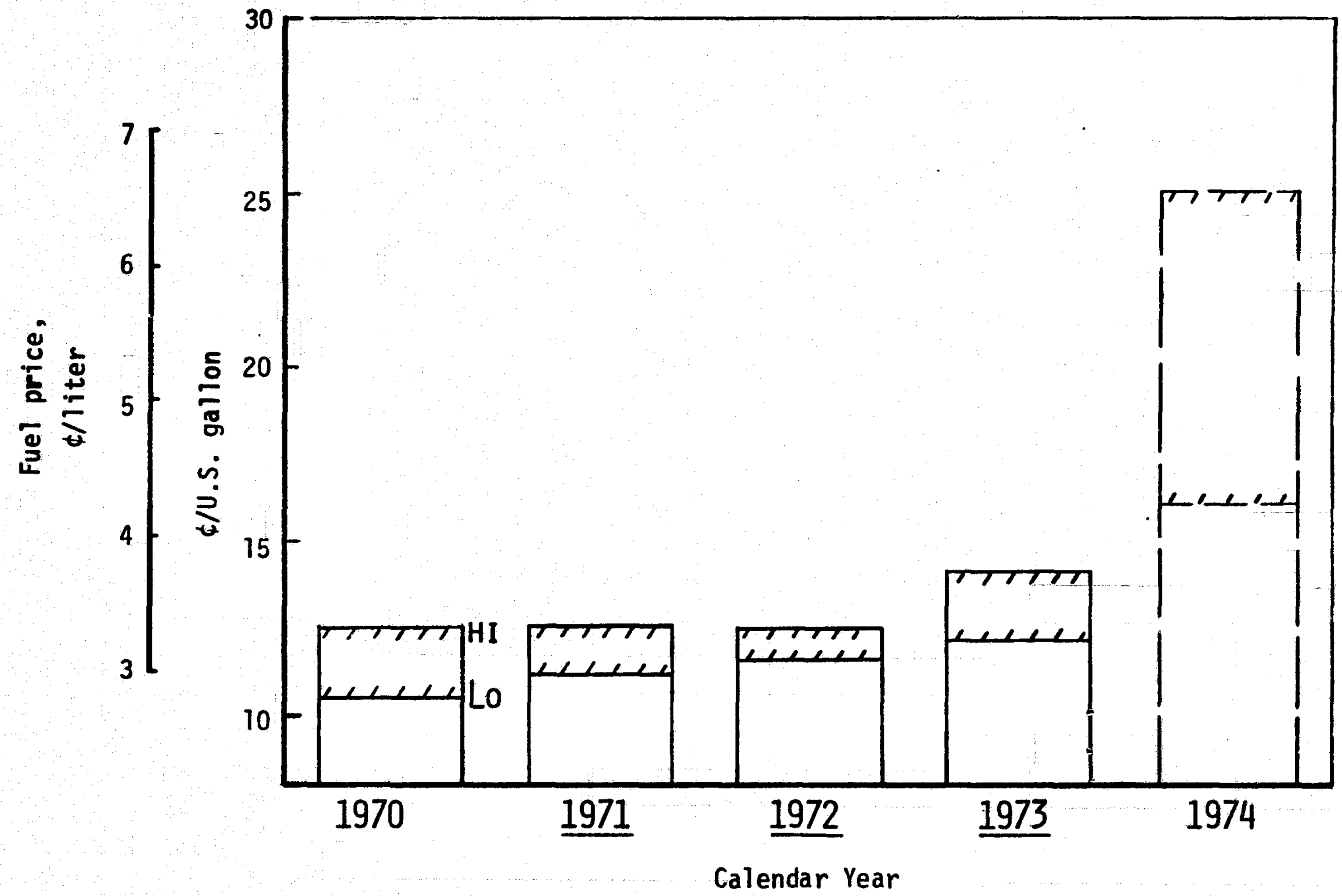

Figure 2-3. - Jet fuel price trend

[U.S. domestic operations]

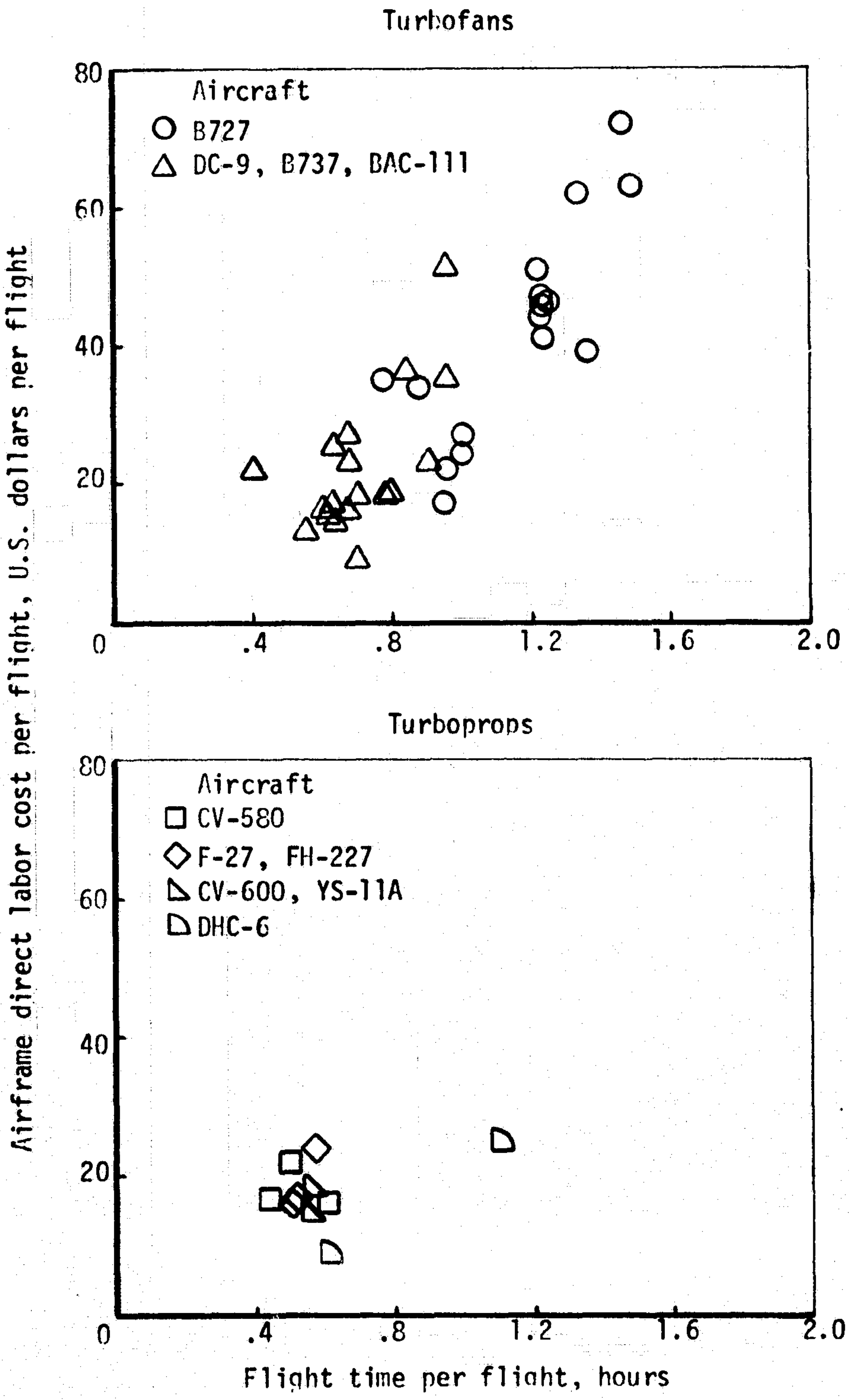

Figure 2-4. - Airframe direct labor cost correlation

[1971-73 operations, 1973 U.S. dollars]

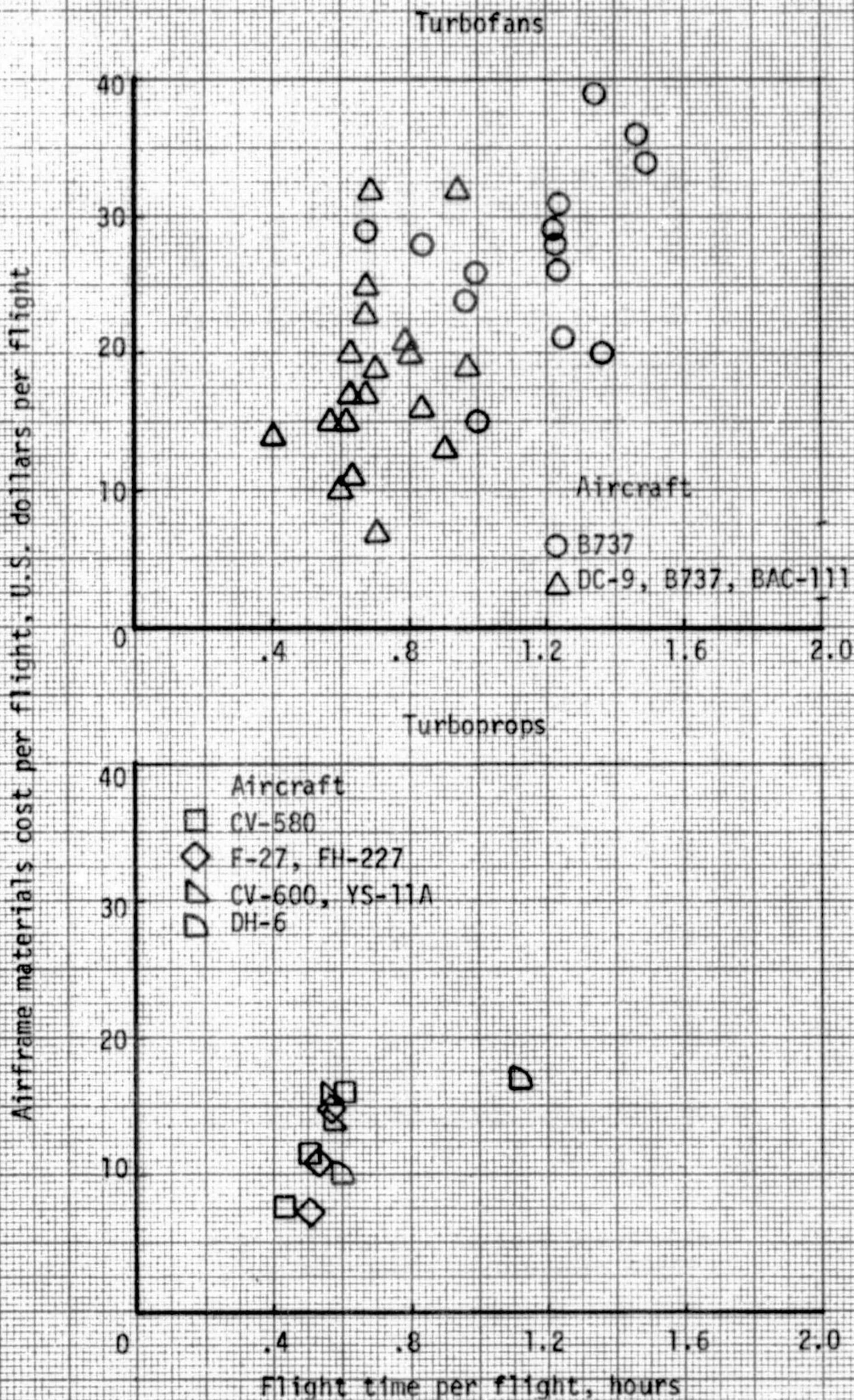

Figure 2-5. - Airframe maintenance materials cost correlation
[1971-73 operations, 1973 U.S. dollars]

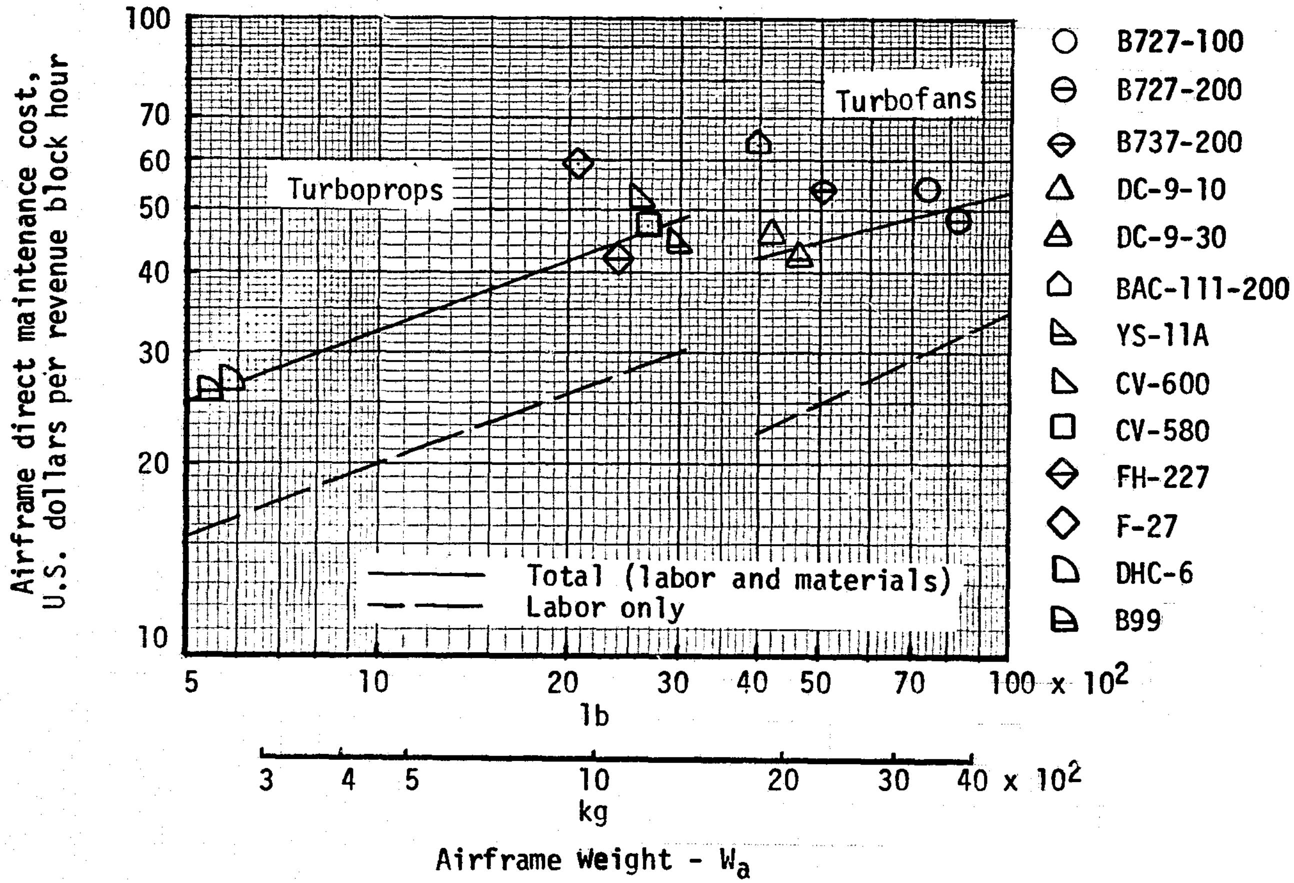

Figure 2-6. - Airframe direct maintenance cost trends
[1971-1973 operations, 1973 U.S. dollars]

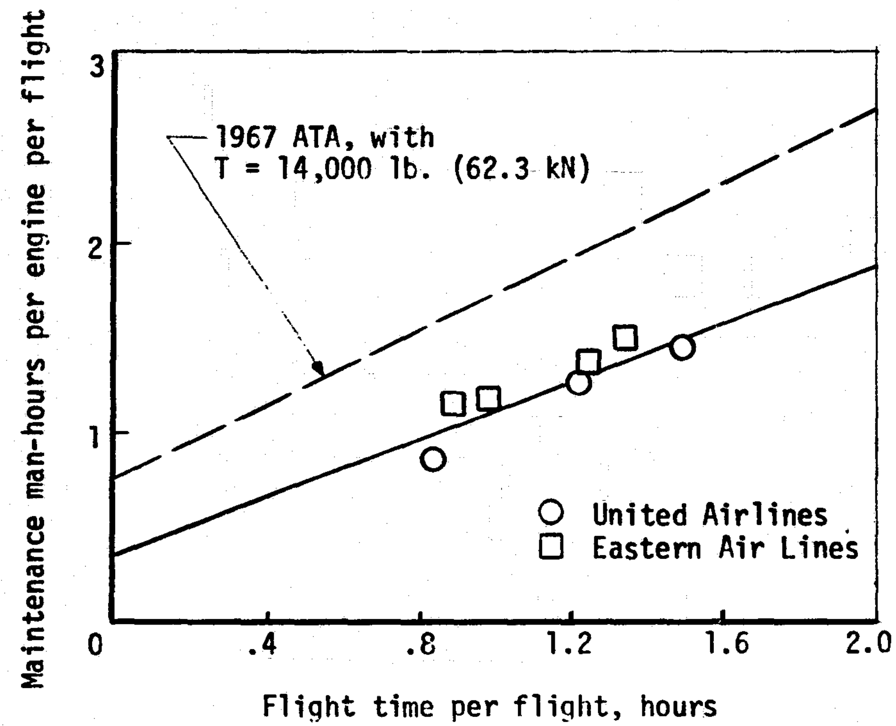

Figure 2-7. - Turbofan engine maintenance labor comparison
[1967 ATA versus 1971-73 JT8D actuals]

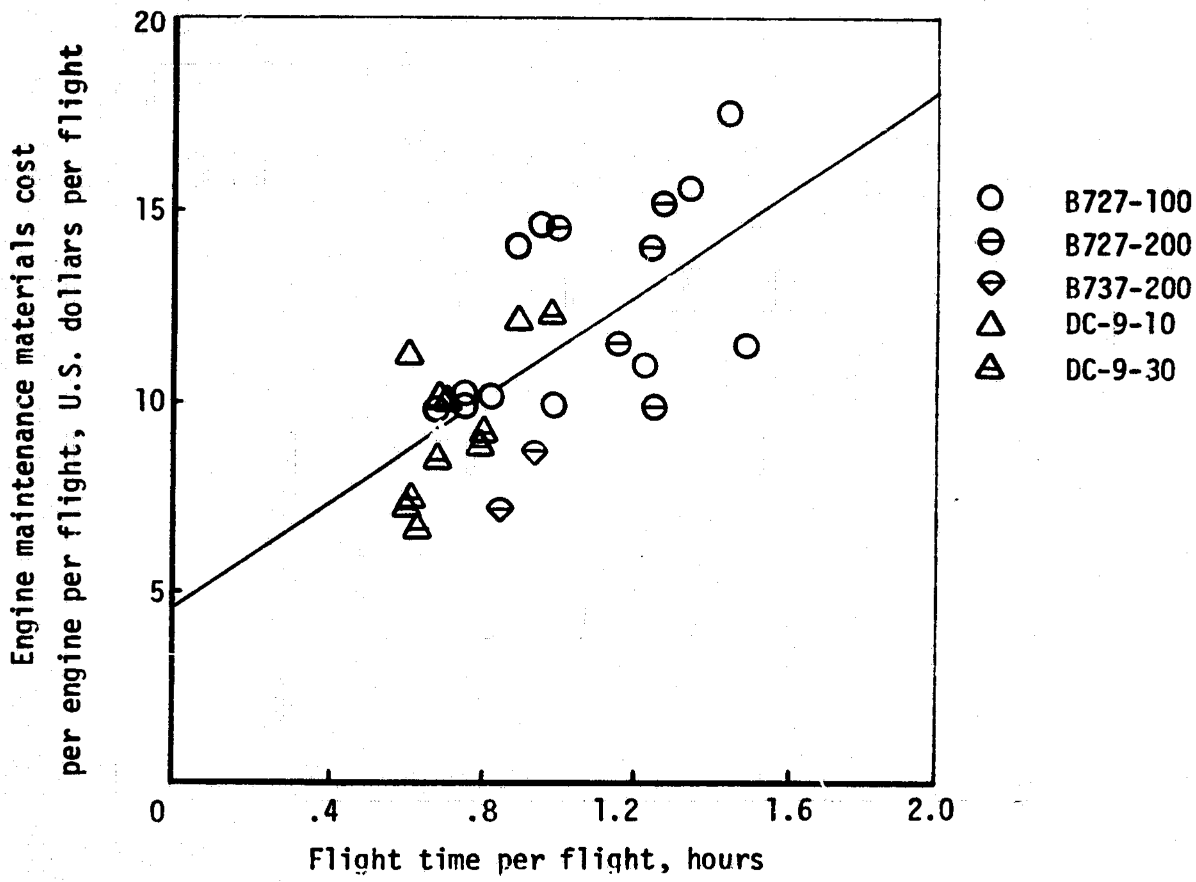

Figure 2-8. - Turbofan engine maintenance materials cost correlation

[JT8D engines, 1973 U.S. dollars]

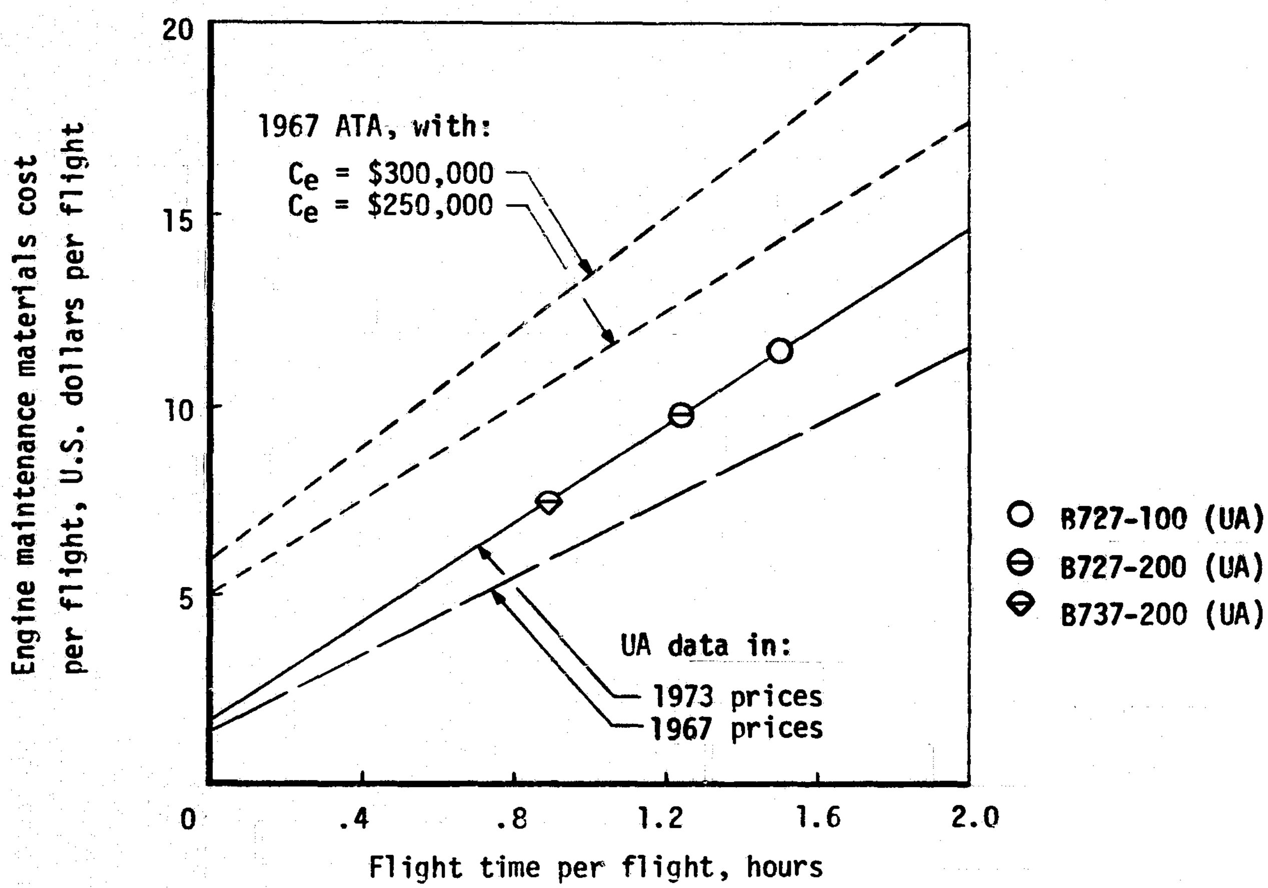

Figure 2-9. - JT8D engine maintenance materials cost comparison

[Airline actuals (United Airlines) versus 1967 ATA]

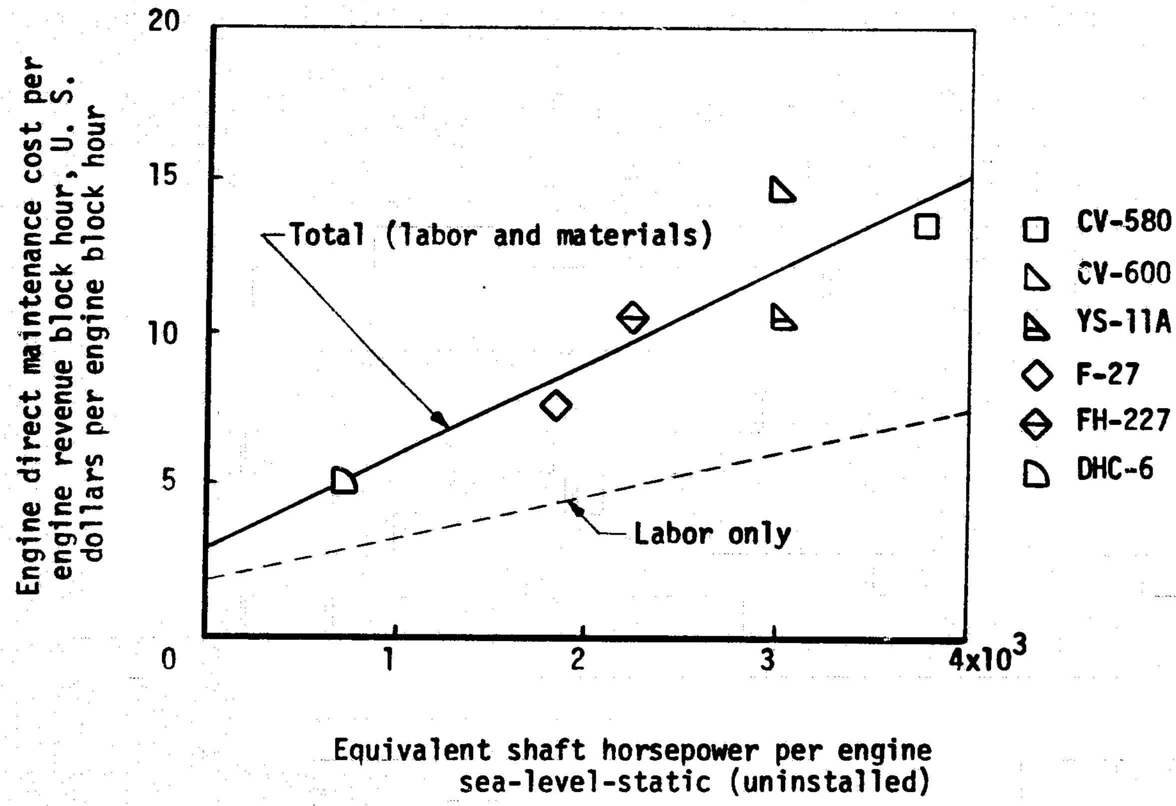

Figure 2-10. - Turboprop engine direct maintenance cost trends
[1971-73 operations, 1973 U.S. dollars]

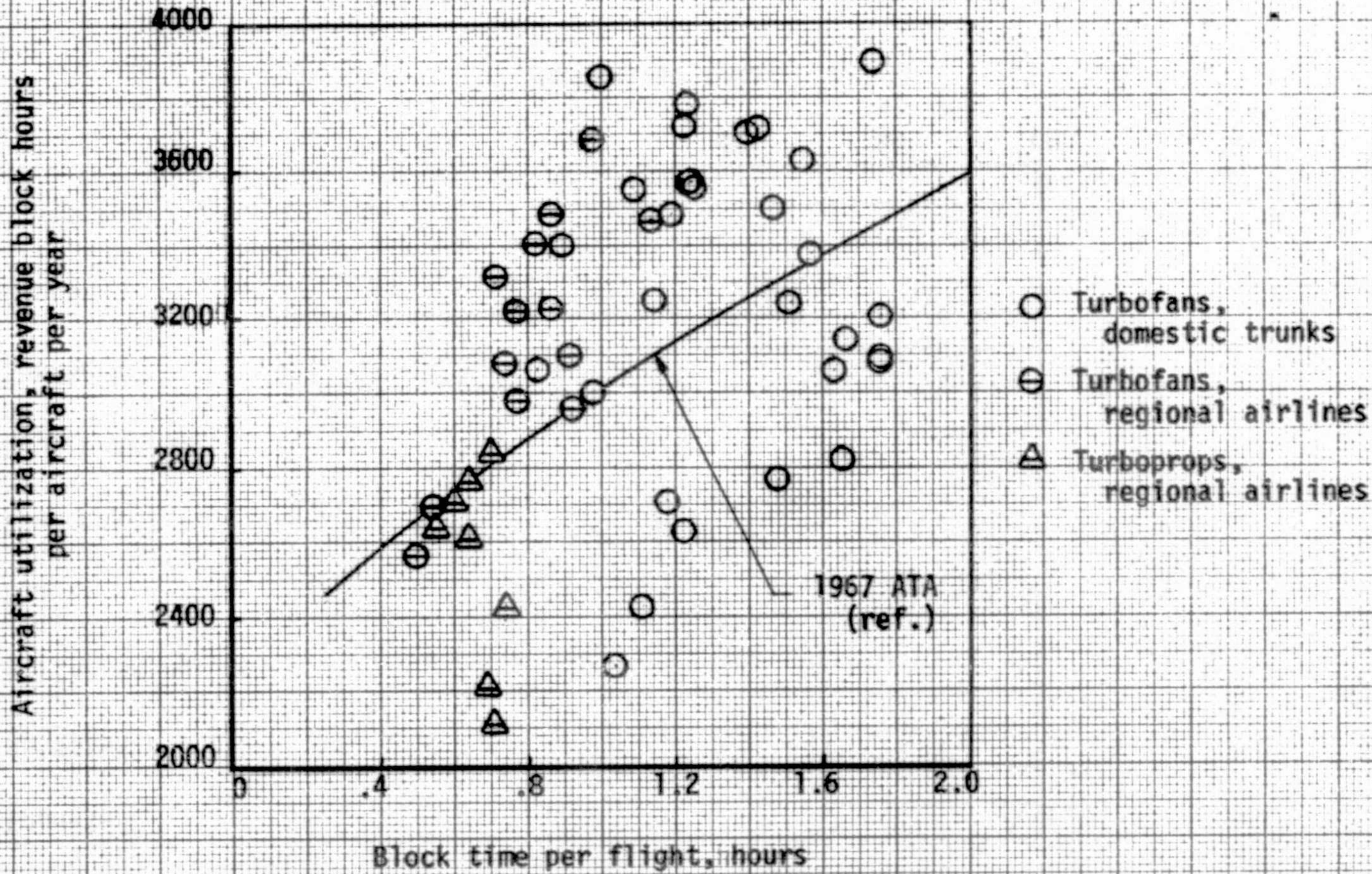

Figure 2-11. - Aircraft utilization correlation (1973 domestic operations)

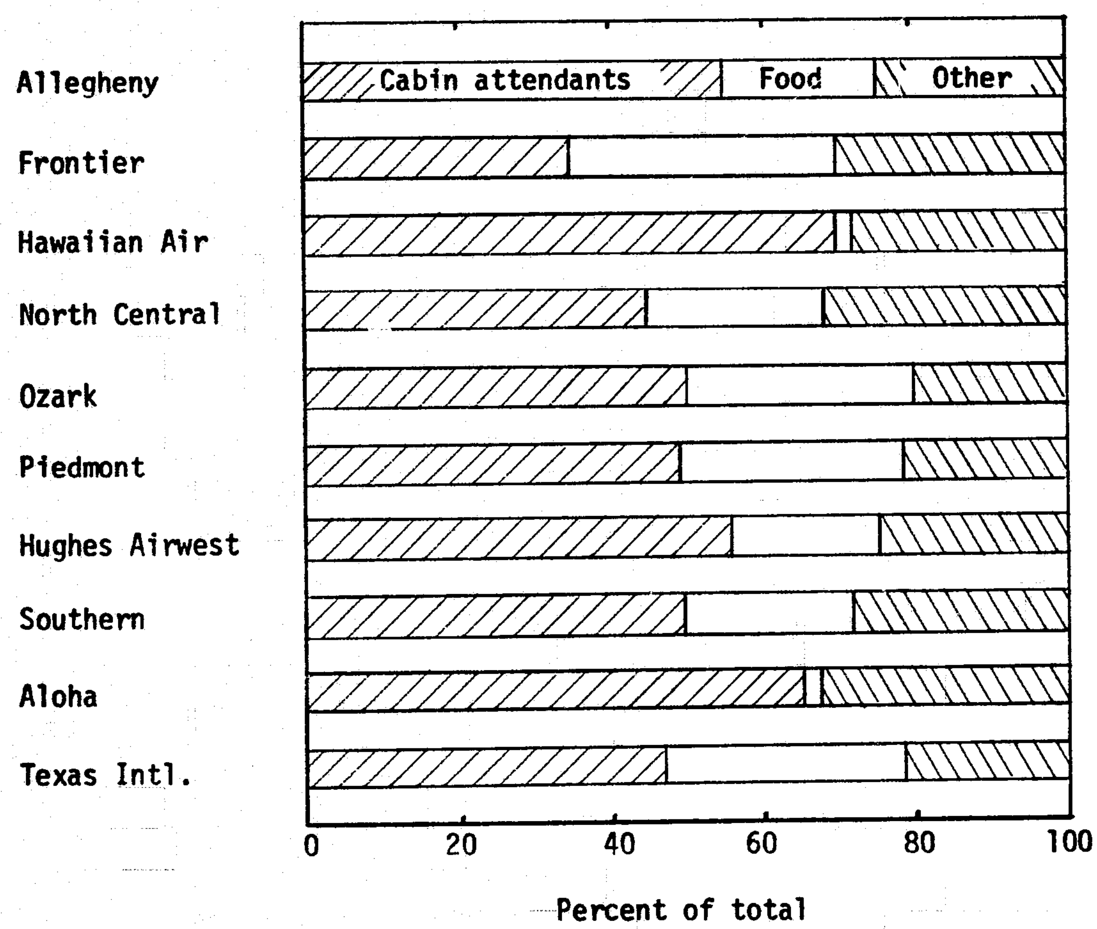

Figure 2-12. - Passenger service expense distributions
[1973 operations]

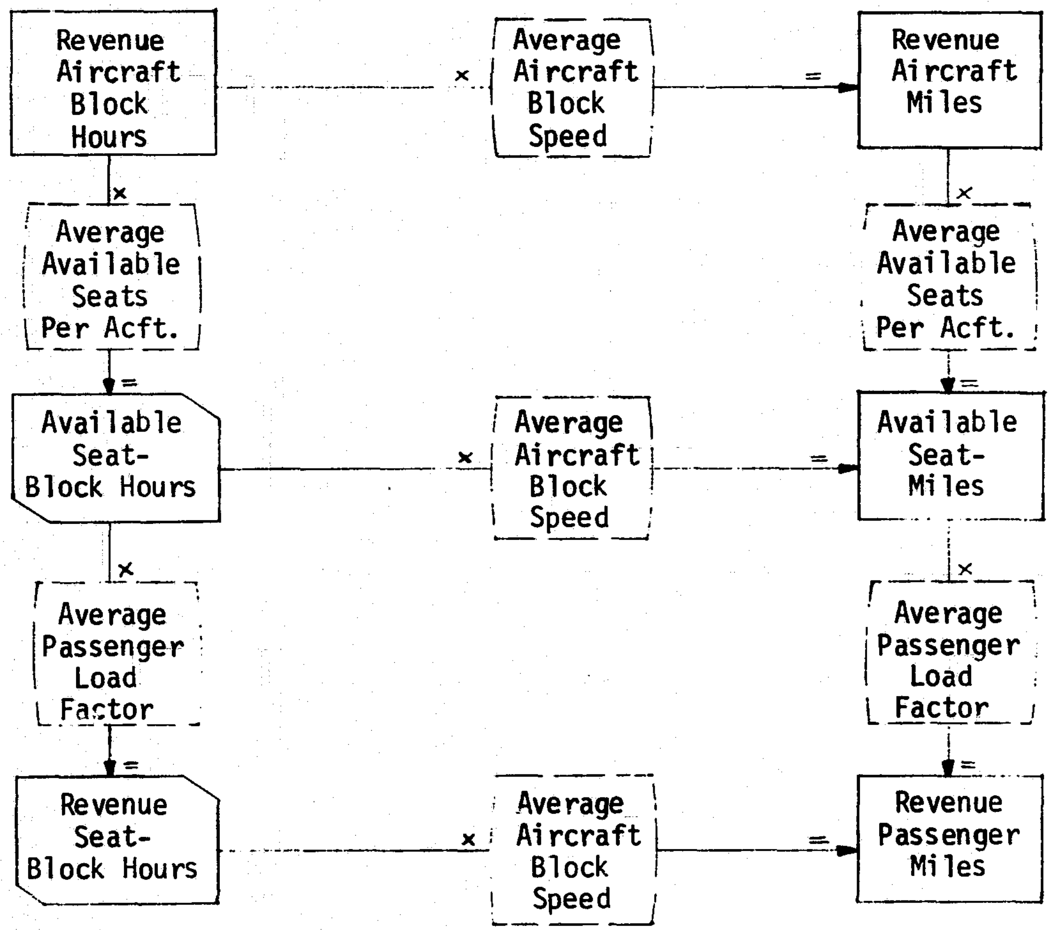

Figure 2-13. - Parameter interrelationships
[CAB airline statistics]

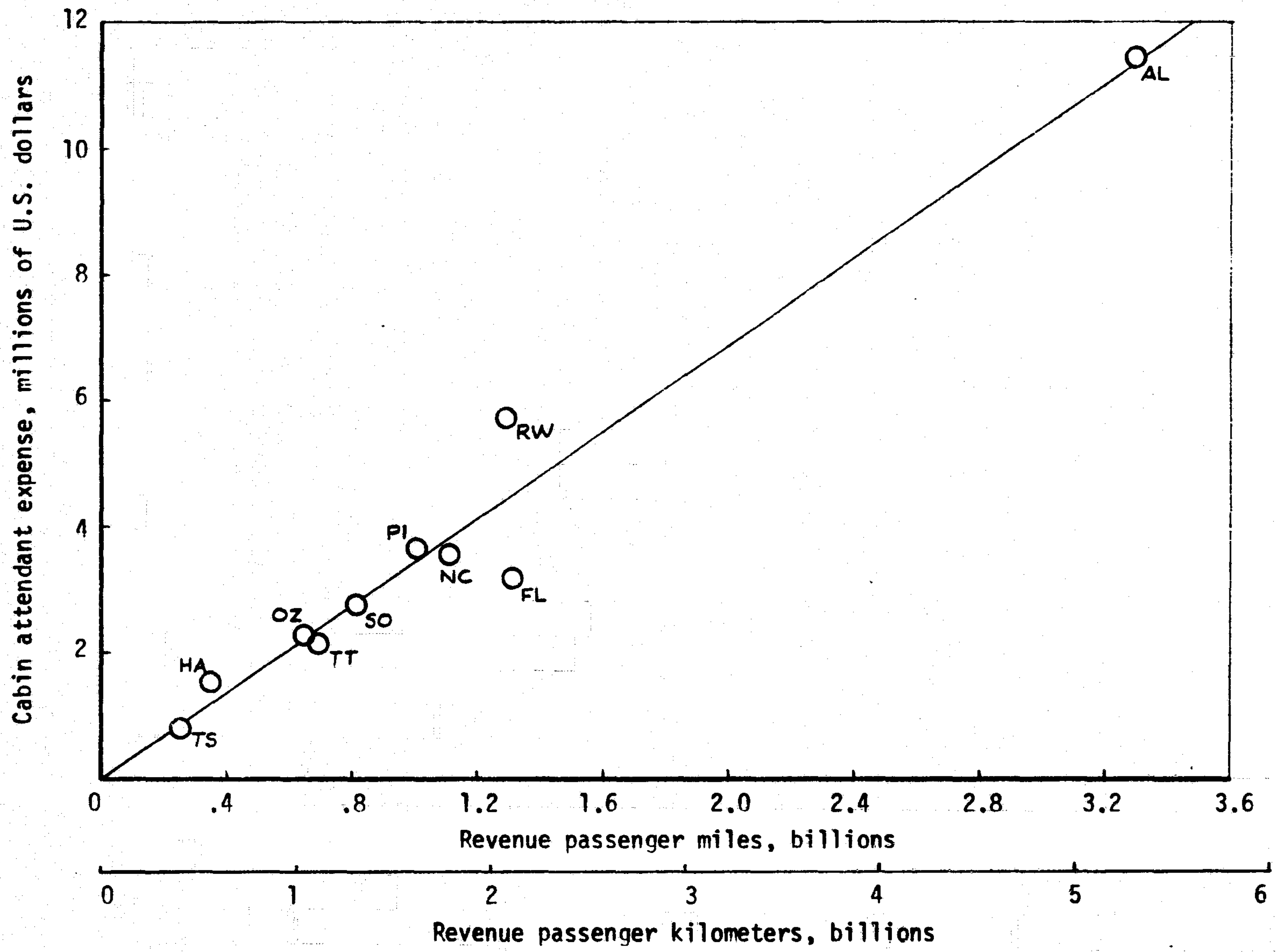

Figure 2-14. - Cabin attendant expense correlation
[1973 operations]

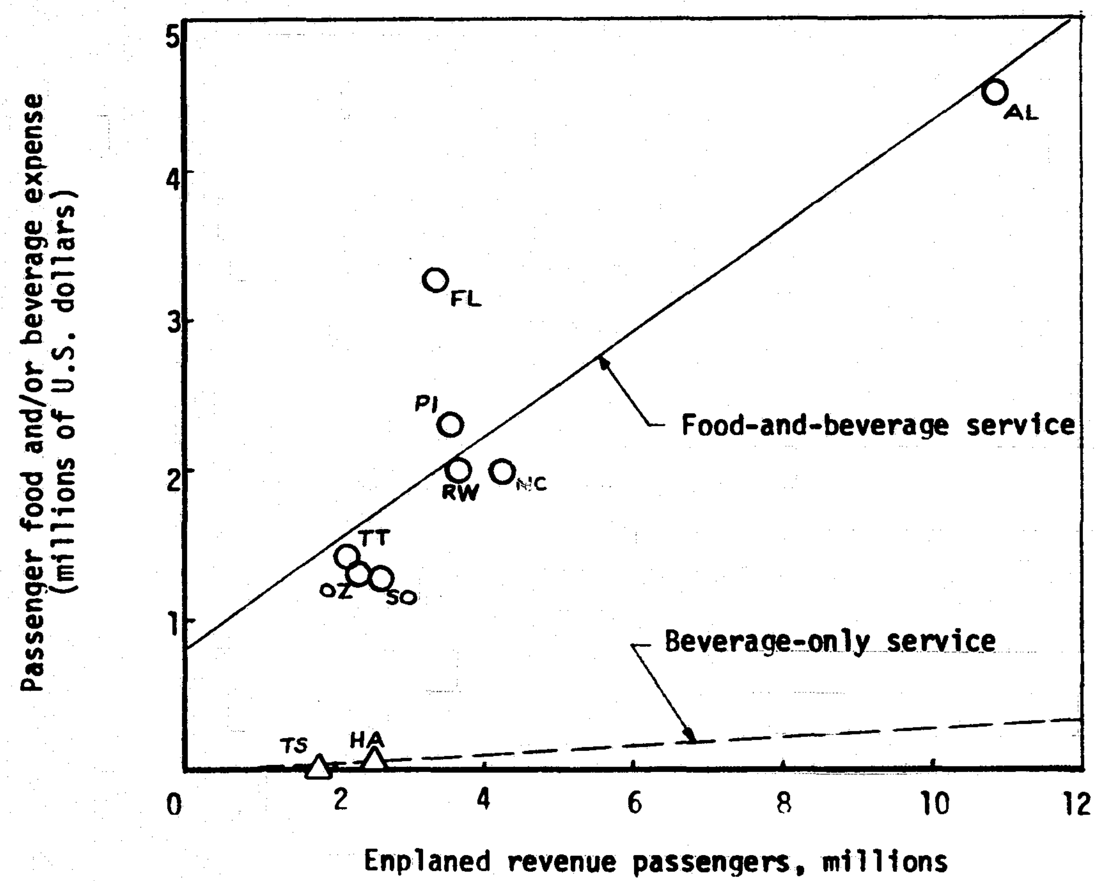

Figure 2-15. - Passenger food and/or beverage expense correlation
[1973 operations]

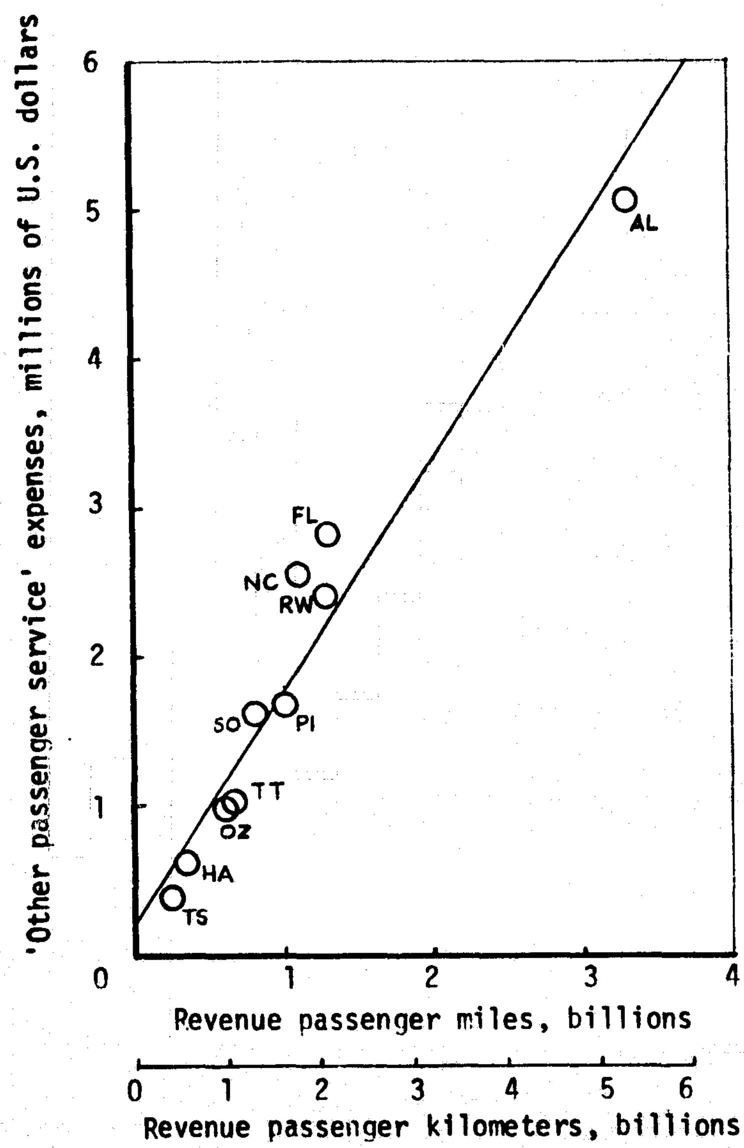

Figure 2-16. - 'Other passenger service' expense correlation
[1973 operations]

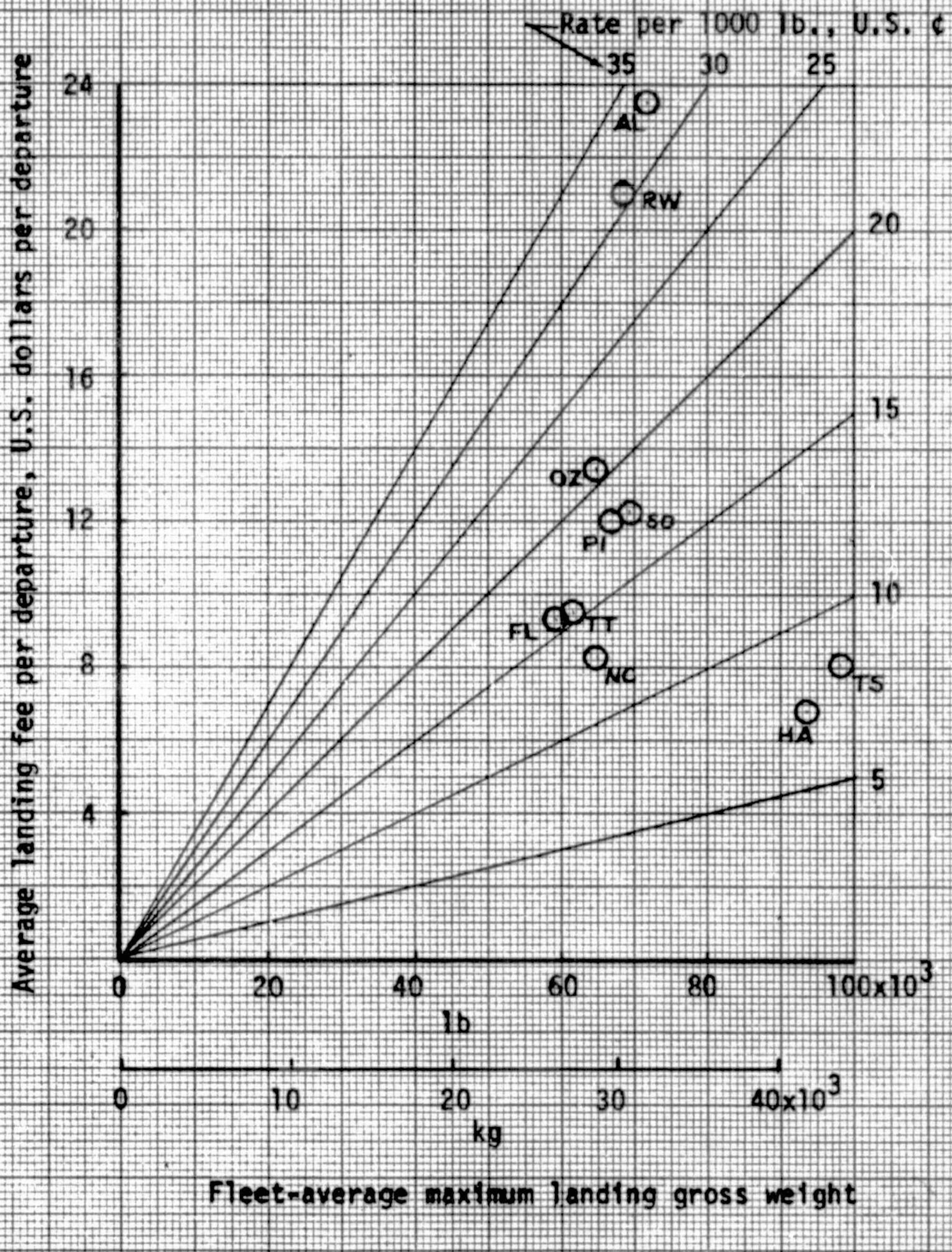

Figure 2-17. - Regional airline landing fees
[1973 operations]

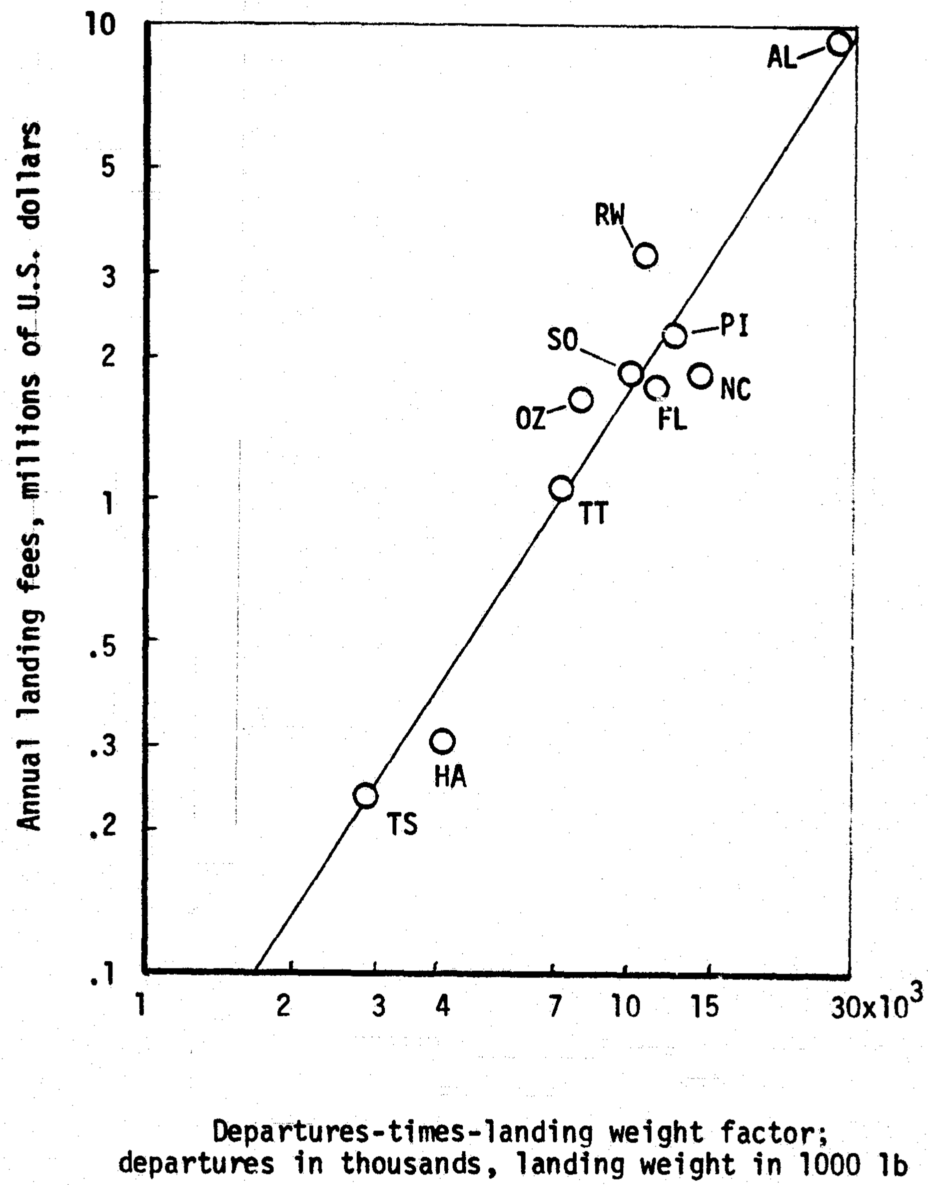

Figure 2-18. - Landing fee expense correlation
[1973 operations]

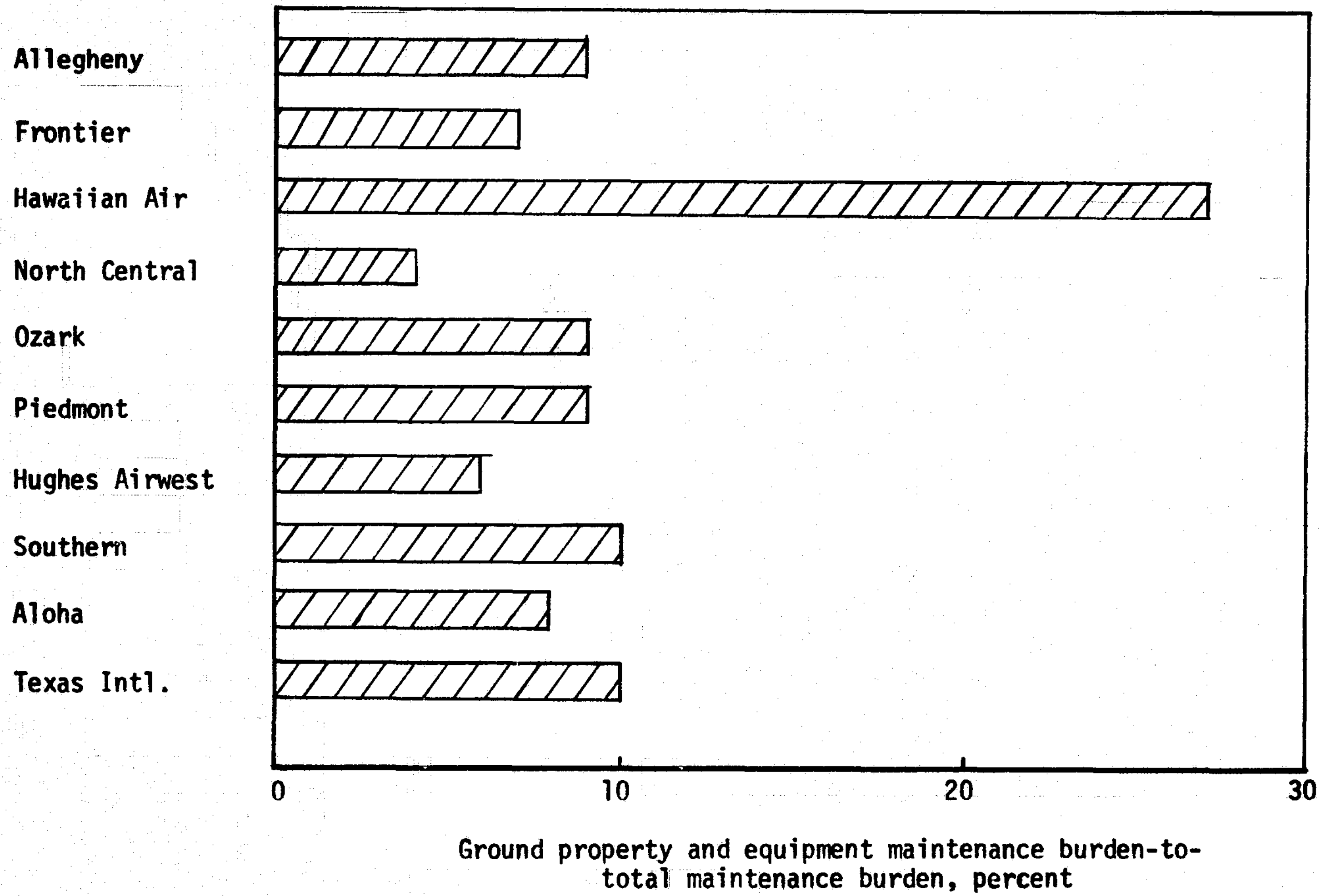

Figure 2-19. - Ground property and equipment maintenance burden allocated

[1973 operations]

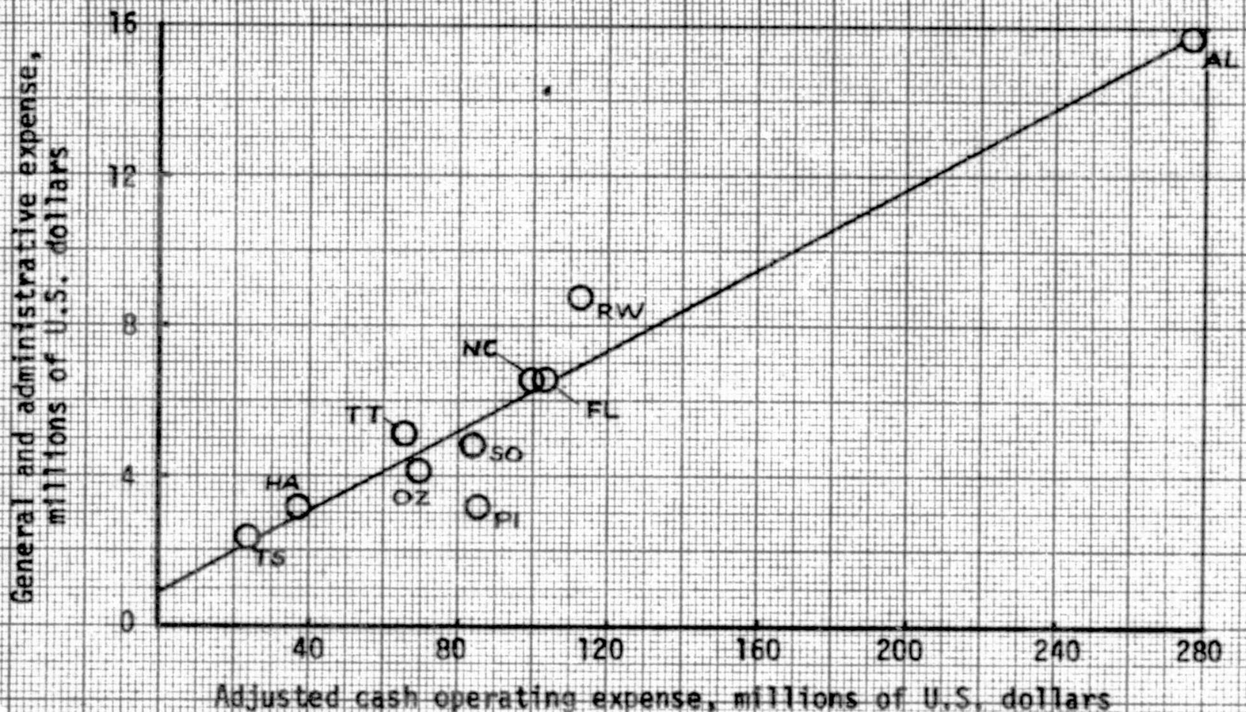

Figure 2-20. - General and administrative expense correlation
[1973 operations]

TABLE 2-1. - AIRCRAFT INSURANCE RATE TRENDS

[CAB Accounts 5155.1, 5155.2, 5158]

AIRLINE/AIRCRAFT	INSURANCE RATE (% ACFT. PRICE)					
	1968	1969	1970	1971	1972	1973
PIEDMONT						
FH-227	1.4	1.6	1.3	0.7	0.01	0.5
YS-11	1.5	1.5	1.3	1.3	1.1	0.9
B737-200	1.7	1.8	1.6	1.7	1.6	1.5
OZARK						
DC-9-10	1.4	1.5	1.6	1.4	1.5	0.7
DC-9-30	1.2	1.5	1.7	1.1	1.3	0.9

SUGGESTED AVERAGE RATE =

1.5% AIRCRAFT PRICE

TABLE 2-2

APPLIED MAINTENANCE BURDEN-TO-DIRECT LABOR RATIO

[Regional Airlines]

Airline	1971	1972	1973
Allegheny	2.22	1.95	1.84
Frontier	1.61	1.60	1.55
Hawaiian Air	1.37	1.44	1.39
North Central	2.22	2.15	2.22
Ozark	1.56	1.54	1.80
Piedmont	1.81	1.78	1.65
Hughes Airwest	1.27	1.35	1.23
Southern	1.34	1.60	2.03
Aloha	1.93	1.83	1.81
Texas International	1.63	1.93	1.89
Regional Average	1.70	1.72	1.74

TABLE 2-3

APPLIED MAINTENANCE BURDEN-TO-DIRECT LABOR RATIO

[Domestic trunks]

Airline	Aircraft	1971	1972	1973
American	BAC-111-400	2.36	2.61	2.59
	727-100	2.38	2.62	2.56
	727-200	2.35	2.62	2.56
Braniff	BAC-111-200	1.89	1.84	2.17
	727-100C/QC	1.90	1.94	2.13
	727-100	1.89	1.96	2.13
	727-200	1.89	1.96	2.12
Continental	DC-9-10RC	2.31	2.51	2.82
	727-200	2.01	2.26	2.57
Delta	727-100	-	2.13	2.25
	727-200	-	2.13	2.26
	DC-9-10	2.45	2.19	2.25
	DC-9-30	2.44	2.19	2.25
Eastern	727-100C/QC	1.56	1.58	1.76
	727-100	1.58	1.58	1.77
	727-200	1.58	1.54	1.77
	DC-9-10	1.57	1.57	1.78
	DC-9-30	1.56	1.55	1.78
National	727-100	2.14	2.31	2.60
	727-200	2.14	2.31	2.59
Northwest	727-100	1.41	1.59	1.31
	727-200	1.41	1.56	1.31
TWA	727-100C/QC	1.98	1.98	2.06
	727-100	2.00	1.98	2.09
	727-200	1.98	1.98	2.07
	DC-9-10	1.99	1.98	2.07
United	727-100C/QC	1.76	1.76	1.62
	727-100	1.75	1.76	1.62
	727-200	1.75	1.76	1.62
	737-200	1.76	1.76	1.62
Western	727-200	1.17	1.81	1.68
	737-200	1.22	1.85	1.30
Short-Haul Domestic Trunk Average		1.87	1.97	2.03

TABLE 2-4

FLIGHT EQUIPMENT RENTALS RATIOS

[1973 operations]

(Rentals)-to-(Rentals-plus-depreciation) ratios

Regional airlines, total fleet	
AL	0.47
FL	0.44
HA	0.69
NC	0.41
OZ	0.43
PI	0.05
RW	0.72
SO	0.62
TS	0.90
TT	0.55

Domestic trunks, per short-haul aircraft		
AA	727-100	0.03
	727-200	0.73
BN	727-100C/QC	0.19
	727-100	0.19
	727-200	0.38
CO	727-200	0
	DC-9-15F	0
DL	727-200	0.52
	DC-9-30	0.12
EA	DC-9-10	0.97
	DC-9-30	0.60
	727-100	0.25
	727-100C/QC	0.15
	727-200	0.32
NA	727-100	0
	727-200	0
NW	727-100	0
	727-200	0
TW	727-200	0.77
	727-100C/QC	0.29
	727-100	0
	DC-9-10	0
UA	727-200	0.14
	727-100C/QC	0.46
	727-100	0.51
	737-200	0
WA	727-200	0.60
	737-200	0

TABLE 2-5

DEPRECIATION AND RENTALS - FLIGHT EQUIPMENT
[Analysis overview]

- DEPRECIATION VS. RENTALS -- LOCALS VS. TRUNKS
- METHOD OF DEPRECIATION (PREDOMINANTLY STRAIGHT-LINE)
- CAB VS. AIRLINE DEPRECIATION
- AIRCRAFT ACQUISITION PRICE
- SPARES/PARTS PERCENTAGES FOR AIRFRAMES AND ENGINES
  - ROTABLES/REPAIRABLES ONLY
  - TOTAL AIRCRAFT % VS. AIRFRAME % + ENGINE %
- DEPRECIATION PERIOD AND RESIDUAL VALUE
  - TRUNKS VS. LOCALS
  - SPARES VS. AIRCRAFT
  - AIRCRAFT TYPE DIFFERENTIATION
- DEPRECIATION RELATION TO UTILIZATION

TABLE 2-6. - ROTABLE (DEPRECIABLE) SPARES/PARTS PERCENTAGES

1973 CAB Form 41 data

Spares/parts percentage, based on initial cost			
	Method I:	Method II, subsystem basis:	
Airline	Total aircraft basis	Airframe and other flight equipment	Engines
North Central	9	6	28
Hughes Airwest	10	7	33
Allegheny	12	6	43
Piedmont	14	9	47
Frontier	12	8	33
Hawaiian Air	13	8	43
1967 ATA Method (ref.)	None	10	40

TABLE 2-7

DOC MODEL - DEFINITION OF INDEPENDENT VARIABLES

TOGW	maximum takeoff gross weight (lb).
VDC	design cruise speed at design cruise altitude (mph).
FCF	flight crew factor: 0 for two-man crew, 1 for three-man crew.
RABH	revenue aircraft block hours per aircraft per year (i.e., aircraft utilization).
FS	fleet size (number of aircraft operated).
FCR	fuel consumption rate (U.S. gallons per aircraft block hour).
IR	insurance rate (percent of initial cost).
FTPF	flight time per flight (hours).
TSLS	maximum takeoff thrust, sea-level static (lb).
ESHP	equivalent shaft horsepower, takeoff rating.
AFPY	aircraft flights per year per aircraft.
RV	residual value (percent of initial cost).
DP	depreciation period (years).
C_f	fuel cost (U.S. dollars per U.S. gallon).
C_t	aircraft unit cost (U.S. dollars).
C_e	engine unit cost (U.S. dollars).
N_e	number of engines per aircraft.
W_a	airframe weight: manufacturer's weight empty less engine weight (lb).

TABLE 2-8

DOC MODEL - INDEPENDENT VARIABLES SUMMARY

Independent variables (a)	Cost model element:				
	Flight crew	Fuel, oil, taxes	Insurance	Maintenance, aircraft	Depreciation, aircraft
TOGW	X	-	-	-	-
VDC	X	-	-	-	-
FCF	X	-	-	-	-
RABH	X	X	-	X	-
FS	X	X	X	X	X
FCR	-	X	-	-	-
IR	-	-	X	-	-
FTPF	-	-	-	X	-
TSLS	-	-	-	X	-
ESHP	-	-	-	X	-
AFPY	-	-	-	X	-
RV	-	-	-	-	X
DP	-	-	-	-	X
C_f	-	X	-	-	-
C_t	-	-	X	-	X
C_e	-	-	-	X	-
N_e	-	-	-	X	-
W_a	-	-	-	X	-

[a] Defined in Table 2-7.

TABLE 2-9

DOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- FLYING OPERATIONS
  - FLIGHT CREW EXPENSE:

$$FCE = \left[27.97 + 33.53\begin{pmatrix}\text{FLIGHT}\\ \text{CREW}\\ \text{FACTOR}\end{pmatrix} + 0.18\left(\frac{\text{TOGW}}{10} + \begin{matrix}\text{DESIGN}\\ \text{CRUISE}\\ \text{SPEED}\end{matrix}\right)\right]\begin{pmatrix}\text{ANNUAL}\\ \text{BLOCK}\\ \text{HOURS PER}\\ \text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{FLEET}\\ \text{SIZE}\end{pmatrix}\left(10^{-6}\right) \quad (1)$$

  - FUEL, OIL AND TAXES:

$$FOT = \left[\begin{pmatrix}\text{FUEL}\\ \text{CONSUMPTION}\\ \text{RATE}\end{pmatrix}\begin{pmatrix}\text{FUEL}\\ \text{COST}\end{pmatrix}(1.045)\right]\begin{pmatrix}\text{ANNUAL}\\ \text{BLOCK}\\ \text{HOURS PER}\\ \text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{FLEET}\\ \text{SIZE}\end{pmatrix}\left(10^{-6}\right) \quad (2)$$

  - INSURANCE:

$$INS = \left[\begin{pmatrix}\text{AIRCRAFT}\\ \text{UNIT COST}\end{pmatrix}\begin{pmatrix}\text{INSURANCE}\\ \text{RATE}\end{pmatrix}\right]\begin{pmatrix}\text{FLEET}\\ \text{SIZE}\end{pmatrix}\left(10^{-6}\right) \quad (3)$$

- COMPOSITE FLYING OPERATIONS COST-ESTIMATING RELATIONSHIP:

$$FO = FCE + FOT + INS$$

TABLE 2-9 - CONTINUED

DOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- DIRECT MAINTENANCE - TURBOFAN AIRCRAFT:
  - AIRFRAME DIRECT MAINTENANCE:

$$ADMTF = \left[2.8 \left(\text{AIRFRAME WEIGHT}\right)^{0.256}\right]\left(\begin{array}{c}\text{ANNUAL}\\ \text{BLOCK}\\ \text{HOURS PER}\\ \text{AIRCRAFT}\end{array}\right)\left(\begin{array}{c}\text{FLEET}\\ \text{SIZE}\end{array}\right)\left(10^{-6}\right) \qquad (4)$$

  - AIRFRAME LABOR CONTENT:

$$ALCTF = \left[0.14 \left(\text{AIRFRAME WEIGHT}\right)^{0.481}\right]\left(\begin{array}{c}\text{ANNUAL}\\ \text{BLOCK}\\ \text{HOURS PER}\\ \text{AIRCRAFT}\end{array}\right)\left(\begin{array}{c}\text{FLEET}\\ \text{SIZE}\end{array}\right)\left(10^{-6}\right) \qquad (5)$$

TABLE 2-9. - CONTINUED

DOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- DIRECT MAINTENANCE - TURBOPROP AIRCRAFT:
  - AIRFRAME DIRECT MAINTENANCE:

$$\text{ADMTP} = \left[1.2\begin{pmatrix}\text{AIRFRAME}\\ \text{WEIGHT}\end{pmatrix}^{0.358}\right]\begin{pmatrix}\text{ANNUAL}\\ \text{BLOCK}\\ \text{HOURS PER}\\ \text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{FLEET}\\ \text{SIZE}\end{pmatrix}\left(10^{-6}\right) \tag{6}$$

  - AIRFRAME LABOR CONTENT:

$$\text{ALCTP} = \left[0.66\begin{pmatrix}\text{AIRFRAME}\\ \text{WEIGHT}\end{pmatrix}^{0.371}\right]\begin{pmatrix}\text{ANNUAL}\\ \text{BLOCK}\\ \text{HOURS PER}\\ \text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{FLEET}\\ \text{SIZE}\end{pmatrix}\left(10^{-6}\right) \tag{7}$$

TABLE 2-9 - CONTINUED

DOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- DIRECT MAINTENANCE - TURBOFAN AIRCRAFT:
  - ENGINE DIRECT LABOR

$$EDLTF = \left[2.61 + 5.41\left(\begin{matrix}\text{FLIGHT}\\ \text{TIME PER}\\ \text{FLIGHT}\end{matrix}\right)\right]\left[0.15\ \begin{matrix}\text{THRUST}\\ \text{PER}\\ \text{ENGINE}\end{matrix}\right]^{0.196}\left(\begin{matrix}\text{ENGINES}\\ \text{PER}\\ \text{AIRCRAFT}\end{matrix}\right)\left(\begin{matrix}\text{AIRCRAFT}\\ \text{FLIGHTS}\\ \text{PER YEAR}\end{matrix}\right)\left(\begin{matrix}\text{FLEET}\\ \text{SIZE}\end{matrix}\right)\left(10^{-6}\right) \qquad (8)$$

  - ENGINE MAINTENANCE MATERIALS:

$$EMMTF = \left[10.54\left(\frac{\text{ENGINE COST}}{10^{6}}\right) + 15.06\left(\frac{\text{ENGINE COST}}{10^{6}}\right)\left(\begin{matrix}\text{FLIGHT}\\ \text{TIME PER}\\ \text{FLIGHT}\end{matrix}\right)\right]\left[0.3\ \begin{matrix}\text{THRUST}\\ \text{PER}\\ \text{ENGINE}\end{matrix}\right]^{0.126}\left(\begin{matrix}\text{ENGINES}\\ \text{PER}\\ \text{AIRCRAFT}\end{matrix}\right) \times$$

$$\left(\begin{matrix}\text{AIRCRAFT}\\ \text{FLIGHTS}\\ \text{PER YEAR}\end{matrix}\right)\left(\begin{matrix}\text{FLEET}\\ \text{SIZE}\end{matrix}\right)\left(10^{-6}\right) \qquad (9)$$

TABLE 2-9. - CONTINUED

DOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- DIRECT MAINTENANCE - TURBOPROP AIRCRAFT:
  - ENGINE DIRECT MAINTENANCE:

$$\text{EDMTP} = \left[2.863 + \frac{3.037}{10^3}\begin{pmatrix}\text{EQUIV.}\\ \text{SHAFT HP}\\ \text{PER}\\ \text{ENGINE}\end{pmatrix}\right]\begin{pmatrix}\text{ENGINES}\\ \text{PER}\\ \text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{ANNUAL}\\ \text{BLOCK}\\ \text{HOURS PER}\\ \text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{FLEET}\\ \text{SIZE}\end{pmatrix}\left(10^{-6}\right) \qquad (10)$$

  - ENGINE LABOR CONTENT:

$$\text{ELCTP} = \left[2.037 + \frac{1.357}{10^3}\begin{pmatrix}\text{EQUIV.}\\ \text{SHAFT HP}\\ \text{PER}\\ \text{ENGINE}\end{pmatrix}\right]\begin{pmatrix}\text{ENGINES}\\ \text{PER}\\ \text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{ANNUAL}\\ \text{BLOCK}\\ \text{HOURS PER}\\ \text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{FLEET}\\ \text{SIZE}\end{pmatrix}\left(10^{-6}\right) \qquad (11)$$

TABLE 2-9. - CONCLUDED

DOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- APPLIED MAINTENANCE BURDEN:

$$\text{AMB} = 1.88\left[\text{AIRFRAME LABOR} + \text{ENGINE LABOR}\right] \qquad (12)$$

- DEPRECIATION - FLIGHT EQUIPMENT:

$$\text{DFE} = \begin{pmatrix}\text{AIRCRAFT}\\ \text{UNIT}\\ \text{COST}\end{pmatrix}\underset{\left(1.12^{*}\right)}{\begin{pmatrix}\text{AIRCRAFT}\\ \text{SPARES}\\ \text{FACTOR}\end{pmatrix}}\underset{\left(1 - .15^{*}\right)}{\left(1 - \begin{matrix}\text{RESIDUAL}\\ \text{VALUE}\end{matrix}\right)}\begin{pmatrix}\text{FLEET}\\ \text{SIZE}\end{pmatrix}\left(10^{-6}\right)\underset{\left(\frac{1}{\text{12 YEARS}}{}^{*}\right)}{\left(\frac{1}{\text{DEPREC. PERIOD}}\right)} \qquad (13)$$

* COST MODEL AVERAGE VALUES

TABLE 2-10

AIRCRAFT AND TRAFFIC SERVICING EXPENSE DISTRIBUTIONS

[1973 Operations]

Airline	Percent of total 6400		
	Aircraft Servicing (6100)	Traffic Servicing (6200)	Servicing Administration (6300)
Allegheny	35	63	2
Frontier	24	69	7
Hawaiian Air	21	76	3
North Central	28	65	7
Ozark (Partial Operations)	38	54	8
Piedmont	34	65	1
Hughes Airwest	35	60	5
Southern	36	64	Included in 6100 & 6200
Aloha	Not required for Group II Carriers		
Texas International	33	63	4

TABLE 2-11

1973 ON-LINE STATION PERFORMANCE

[CAB Form 41; Schedules P-9.2, T-2, T-3]

Airline	Average Number of Stations	Passenger enplanements per station	Aircraft departures per station
Allegheny	70	155,000	5,600
Aloha	8	227,000	3,600
Frontier	91	37,000	2,100
Hawaiian Air	8	319,000	5,600
Hughes Airwest	72	51,000	2,200
North Central	72	59,000	3,000
Ozark	51	45,000	2,400
Piedmont	50	71,000	3,700
Southern	54	52,000	2,900
Texas International	49	44,000	2,400

TABLE 2-12

OPERATING PROPERTY AND EQUIPMENT SUMMARY

[Status as of 12-31-73]

AIRLINE	FLIGHT EQUIPMENT	GROUND PROPERTY & EQUIPMENT	DOLLAR RATIO FLIGHT:GROUND
ALLEGHENY	$ 211.609 M	$24.356 M	8.7:1
FRONTIER	71.519	9.524	7.5:1
HAWAIIAN AIR	20.188	4.378	4.6:1
HUGHES AIRWEST	61.307	5.989	10.2:1
NORTH CENTRAL	95.492	11.042	8.7:1
PIEDMONT	123.490	10.663	11.6:1

TABLE 2-13

IOC MODEL - INDEPENDENT VARIABLES SUMMARY

Cost model element	Independent variables[a]
Cabin attendants	RPM
Food and/or beverage	ERP
Other passenger service	RPM
Aircraft control and line servicing	RAM
Aircraft landing fees	RAD, ALGW
Traffic servicing	RTM, RAD
Promotion and sales	ERP, RPM
Ground property and equipment	DFE
GP&E depreciation content	DFE
General and administrative	ACOE

[a] Defined in Table 2-14

TABLE 2-14

IOC MODEL - DEFINITION OF INDEPENDENT VARIABLES

RPM	revenue passenger (statute) miles per year.
ERP	enplaned revenue passengers per year.
RAM	revenue aircraft (statute) miles per year.
RAD	fleet revenue aircraft departures per year: aircraft flights (i.e., departures) per year per aircraft (AFPY) times fleet size (FS).
ALGW	fleet-average maximum landing gross weight per flight.
RTM	revenue ton-(statute) miles per year; in this model: RTM = (0.1113) (RPM).
DFE	flight equipment depreciation expense per year: total fleet including spares/spare parts.
ACOE	adjusted cash operating expense per year: total operating expense less aircraft depreciation, ground property and equipment depreciation, amortization and general and administrative expenses.

TABLE 2-15

IOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- PASSENGER SERVICE EXPENSE
  - CABIN ATTENDANT EXPENSE:

$$CAE = -0.023 + 3.466 \left[\underset{\text{(BILLIONS)}}{\text{REVENUE PASSENGER MILES}} \right] \tag{14}$$

  - FOOD AND BEVERAGE EXPENSE:

$$FBE = 0.831 + 0.35 \left[\underset{\text{(MILLIONS)}}{\text{ENPLANED REVENUE PASSENGERS}} \right] \tag{15}$$

OR

  - BEVERAGE-ONLY EXPENSE:

$$BOE = -0.026 + 0.03 \left[\underset{\text{(MILLIONS)}}{\text{ENPLANED REVENUE PASSENGERS}} \right] \tag{16}$$

  - OTHER PASSENGER SERVICE EXPENSE:

$$OPSE = 0.232 + 1.564 \left[\underset{\text{(MILLIONS)}}{\text{REVENUE PASSENGER MILES}} \right] \tag{17}$$

- COMPOSITE COST-ESTIMATING RELATIONSHIP:

$$PSE = CAE + \begin{matrix} FBE \\ \text{OR} \\ BOE \end{matrix} + OPSE$$

TABLE 2-15 - CONTINUED

IOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- AIRCRAFT AND TRAFFIC SERVICING EXPENSE
  - AIRCRAFT CONTROL AND LINE SERVICING EXPENSE:

$$\text{ACLSE} = 0.86 + 0.199\left[\underset{\text{(MILLIONS)}}{\text{REVENUE AIRCRAFT MILES}}\right] \quad (18)$$

  - AIRCRAFT LANDING FEES EXPENSE:

$$\text{ALFE} = \left(\frac{0.688}{10^6}\right)\left[\underset{\text{(1000 LB)}}{\left(\begin{array}{c}\text{LANDING}\\\text{GROSS}\\\text{WEIGHT}\end{array}\right)}\ \underset{\text{(THOUSANDS)}}{\left(\begin{array}{c}\text{AIRCRAFT}\\\text{DEPARTURES}\\\text{PER YEAR}\end{array}\right)}\ \left(\begin{array}{c}\text{FLEET}\\\text{SIZE}\end{array}\right)^{1.6015}\right] \quad (19)$$

  - TRAFFIC SERVICING EXPENSE:

$$\text{TSE} = 1.31 + 0.082\left[\underset{\text{(MILLIONS)}}{\text{REVENUE TON-MILES}}\right] + 0.041\underset{\text{(THOUSANDS)}}{\left[\begin{array}{c}\text{REVENUE}\\\text{AIRCRAFT}\\\text{DEPARTURES}\end{array}\right]} \quad (20)$$

- COMPOSITE COST-ESTIMATING RELATIONSHIP:

$$\text{ATSE} = \text{ACLSE} + \text{ALFE} + \text{TSE}$$

7

TABLE 2-15.- CONTINUED

IOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- PROMOTION AND SALES EXPENSE:

$$\text{PASE} = 1.785 + 1.201 \left[\begin{array}{c} \text{ENPLANED} \\ \text{REVENUE} \\ \text{PASSENGERS} \end{array} \right]_{\text{(MILLIONS)}} + 4.716 \left[\begin{array}{c} \text{REVENUE} \\ \text{PASSENGER} \\ \text{MILES} \end{array} \right]_{\text{(BILLIONS)}} \quad (21)$$

- GROUND PROPERTY AND EQUIPMENT EXPENSE:

$$\text{GPEE} = -0.369 + 0.227 \left[\begin{array}{c} \text{FLIGHT EQUIPMENT} \\ \text{DEPRECIATION EXPENSE} \\ \text{(\$MILLIONS)} \end{array} \right] \quad (22)$$

- GPEE DEPRECIATION CONTENT:

$$\text{GPDC} = -0.244 + 0.099 \left[\begin{array}{c} \text{FLIGHT EQUIPMENT} \\ \text{DEPRECIATION EXPENSE} \\ \text{(\$MILLIONS)} \end{array} \right] \quad (23)$$

TABLE 2-15. - CONCLUDED

IOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- AMORTIZATION (OF DEVELOPMENTAL AND PREOPERATING EXPENSE):

$$ADPE = -0.094 + 0.019 \left[\begin{array}{c} \text{REVENUE AIRCRAFT MILES} \\ \text{(MILLIONS)} \end{array} \right] \qquad (24)$$

- GENERAL AND ADMINISTRATIVE EXPENSE:

$$GAE = 0.916 + 0.054 \left[\begin{array}{c} \text{TOTAL OPERATING COST} \\ \text{LESS} \\ \text{FLIGHT EQUIPMENT DEPR. EXPENSE} \\ \text{LESS} \\ \text{GROUND PROP. DEPRECIATION EXPENSE} \\ \text{LESS} \\ \text{AMORTIZATION EXPENSE} \\ \text{LESS} \\ \text{GENERAL AND ADMIN. EXPENSE} \\ \text{(\$ MILLIONS)} \end{array} \right] \qquad (25)$$

TABLE 2-16.- TOTAL OPERATING COST SUMMARY

TOTAL OPERATING COST

Direct Operating Cost			
Flying Operations	Flight crew		
Flying Operations	Fuel, oil and taxes		
Flying Operations	Insurance		
Direct Maintenance	Airframe	Turbofan: total direct	Turboprop: total direct
Direct Maintenance	Airframe	Turbofan: labor content (a)(b)	Turboprop: labor content (a)(b)
Direct Maintenance	Engine	Turbofan: direct labor (a)	Turboprop: total direct
Direct Maintenance	Engine	Turbofan: maintenance materials	Turboprop: labor content (a)(b)
Applied Maintenance Burden			
Depreciation-Flight Equipment			

Indirect Operating Cost	
Passenger Service	Cabin attendants
Passenger Service	Food-and-beverage or Beverage-only
Passenger Service	Other passenger service
Aircraft and Traffic Servicing	Aircraft control and line servicing
Aircraft and Traffic Servicing	Aircraft landing fees
Aircraft and Traffic Servicing	Traffic servicing
Promotion and sales	
Ground property and equipment	
GP&E depreciation content (c)	
Amortization	
General and administrative	

[a] Required for determining applied maintenance burden
[b] Non-additive for DOC
[c] Required for determining general and administrative cost; non-additive for IOC

TABLE 2-17. - COST MODEL SYMBOLICAL SUMMARY

<table>
<tr><td colspan="4">TOC</td></tr>
<tr><td colspan="2">DOC</td><td colspan="2">IOC</td></tr>
<tr><td rowspan="3">FO</td><td>FCE</td><td rowspan="3">PSE</td><td>CAE</td></tr>
<tr><td>FOT</td><td>FBE or BOE</td></tr>
<tr><td>INS</td><td>OPSE</td></tr>
<tr><td rowspan="2">ADMTF
ALCTF (a)</td><td rowspan="2">ADMTP
ALCTP (a)</td><td rowspan="3">ATSE</td><td>ACLSE</td></tr>
<tr><td>ALFE</td></tr>
<tr><td rowspan="2">EDLTF
EMMTF</td><td rowspan="2">EDMTP
ELCTP (a)</td><td>TSE</td></tr>
<tr><td colspan="2">PASE</td></tr>
<tr><td colspan="2">AMB</td><td colspan="2">GPEE
GPDC (b)</td></tr>
<tr><td colspan="2" rowspan="2">DFE</td><td colspan="2">ADPE</td></tr>
<tr><td colspan="2">GAE</td></tr>
</table>

[a] Non-additive for DOC

[b] Non-additive for IOC

3.0 COST MODEL EVALUATION

The cost model evaluation process consisted of several activities. The DOC and IOC models were exercised with a hypothetical aircraft-airline data set. This provided an example of model input and output. Several types of comparisons were made: (1) the results obtained using the short-haul operating cost model were compared with actual aircraft and airline operating costs, as per a study requirement; and (2) the results obtained using the model were compared with the results obtained using the DOC and IOC methods employed by the NASA Medium Density Study (ref. 12). A summary of the cost model evaluations conducted by Air California and United Airlines concludes this section.

3.1 Illustrative Example

The hypothetical aircraft and airline input data which was used to evaluate the short-haul operating cost model is shown in Table 3-1. The aircraft type used in the example is about one-half the size of a DC-9-30. It carried 50 passengers, had a takeoff gross weight of 44,000 pounds (19,955 kg), and was powered by two 8,000-pound (35.6 kN) turbofans. The hypothetical airline used for the example consisted of 60 of these 50-passenger aircraft, each of which flew 3,917 flights per year, averaged 200 statute miles (321 km) per flight, and had an annual utilization of 2,820 revenue block hours. The hypothetical airline data assumed for the illustrative example is typical of one of the regional airlines which formed the principal data base for this cost model. All of the aircraft and airline data listed in Table 3-1 are required to perform one iteration of the model. Since the cost model was not computerized, only this one case was evaluated.

The sample input data produced the results shown in Table 3-2. Each operating cost element, as well as their respective totals (DOC, IOC, TOC), is given in millions of 1973 dollars per year. The airline example used for the test case used the beverage-only option of the IOC model. If the food-and-beverage option had been selected, this particular operating cost would have been $3.3 million per year instead of the $0.19 million shown in the table. The annual operating costs shown in Table 3-2 are indicative of annual airline system-wide operations, but they can be restated in other forms depending on the type of analysis being conducted. This choice of output format must be made by the analyst. A detailed step-by-step explanation of how each of the costs shown in Table 3-2 were calculated is not presented and a user's manual for the cost model was not compiled because of study scope limitations.

3.2 Comparative Analyses

Several types of comparisons were performed with the short-haul operating cost model to illustrate some of its features. A direct operating cost comparison using the 50-passenger aircraft of the test case and the various contemporary aircraft which comprised the data base is shown in Figure 3-1. At the 200-statute mile (321 km) average stage length assumed, the DOC of the sample aircraft is $343 per trip. This was derived by dividing the total annual fleet DOC ($80.51 million) by the total annual revenue aircraft departures (RAD = 235,000). The trip cost for the sample aircraft at the stage length shown in the figure falls near the lower end of the twin-turbofan aircraft group of the data base. However, the characteristics of the sample aircraft are unlike those of the aircraft comprising the twin-turbofan group and its DOC should not be compared with the DOCs of those aircraft. The

commonly-used DOC costs of dollars per aircraft-mile and cents per available seat-mile are obtained by dividing the cost per trip by average stage length and then by the number of available seats per aircraft at that stage length. To illustrate: $343 per trip divided by 200 statute miles (322 km) equals $1.715 per aircraft-mile ($1.07 per aircraft-km); that total, when divided by 50 seats equals 3.43 cents per available seat-mile (2.1 cents per available seat-km). These sample DOCs were selected to represent a typical short-haul airline operation. They would be lower in terms of cost per aircraft-mile or cost per available seat-mile at the design range of the aircraft (500 statute miles, 805 km). The DOCs of a conceptual or advanced transport aircraft are often given only at its design payload-range point to illustrate the lower-cost aspects of that design. However, such a presentation is usually not indicative of realistic airline operating conditions.

Table 3-3 presents a comparison of the annual operating costs and certain traffic and system characteristics of the hypothetical short-haul airline of the test case with similar data from four of the regional airlines which formed the data base. This sample airline would fit between Allegheny and Hughes Airwest if ranked in order of decreasing annual operating cost. This was to be expected if the cost model was properly designed. The ratio of the IOC-to-DOC of 0.892 for the sample airline was within the range of that ratio for the regional airlines for 1973, and provided another check on the validity of the model output. A check of the percentage distribution of the calculated cost elements comprising the TOC of the sample airline indicated good conformance to similar data for the regional airlines for 1973. Since the cost model determines the annual operating cost of an average, or typical, short-haul airline, a comparison of its costs, element by element, with those

of any one airline, whether it be Frontier or North Central or Southern, would not be meaningful.

Comparisons of the predictive capability of the short-haul operating cost model with other DOC/IOC models were made in several ways. The study's DOC method was compared with a DOC model used in the NASA Medium Density Short-Haul Study (ref. 12), and the results are summarized in Table 3-4. For this comparison, the fleet size and the conceptual aircraft type selected were the same as for the illustrative example. However, the DOC method comparison would be just as valid using one aircraft instead of a 60-aircraft fleet. The DOC method from the Medium Density Study (MDS) was restated in 1973 dollars, using the inflation factors provided in that study, to provide an equal price level basis for comparison. The differences between the two models for each element are explained as follows:

- Flight Crew - The model uses 1973 actuals. MDS uses the 1967 ATA formula adjusted at 6 percent per year for inflation.
- Insurance - The model uses 1.5 percent rate. MDS uses 1 percent.
- Depreciation - The model uses 12 years to 15 percent with 12 percent spares. MDS uses 15 years to 15 percent with 10 percent spares.
- Fuel, Oil, Taxes - The model includes a 4.5 percent factor on fuel cost for oil and taxes. MDS does not include this.
- Direct Maintenance - The model us based on industry averages. MDS is based on DAC product support data reflecting DAC aircraft only.

o Maintenance Burden - The model is based on a 1.88 composite airline factor on direct labor, reflecting 1973 operations. MDS uses a 1.8 factor from 1967 ATA DOC.

The differences in insurance, depreciation, and fuel expenses are the result of factor changes and not method changes since the aircraft unit price, utilization, and fuel consumption were identical in both cases. The two elements affected by method differences are flight crew and maintenance. The model total ($20.66 M + $21.37 M) is about 95 percent of the MDS total ($24.53 M + $19.85 M). These differences have been already explained and the model does provide reasonable results.

A second comparison was performed by medium density study project personnel using the actual 50-passenger turbofan baseline aircraft of that study and airline operational analyses with that aircraft. The results are summarized in Table 3-5. Three methods were used for this comparison: (1) DAC-modified DOC and IOC methods, (2) the medium density DOC and IOC methods, and (3) the short-haul operating cost model with the unit fuel cost increased 57 percent and all other cost elements increased 15 percent to provide estimates in 1974 dollars. The price increases used for the short-haul operating cost model are unofficial since the ATA price index data for 1974 had not yet been published at the time this comparison was made. The DOC estimated by the short-haul model is about 4 percent higher than that estimated by the MDS DOC model for two reasons: (1) the preliminary price indexes used in the short-haul model to determine 1974 costs, and (2) the differences in the factors used in the MDS and short-haul models. This difference in factors also resulted in the 4 percent difference in the results shown in Table 3-4,

which was based on a 50-passenger conceptual aircraft. If the factors had been identical in both models, the short-haul DOC model would provide somewhat lower DOCs. The short-haul IOC model provided the lowest IOC, as would be expected, since it was developed from regional airline operations. The MDS method does not estimate IOC by individual cost element; it estimates total IOC as a function of passenger revenue. The significantly higher DAC-modified formula was based on a domestic trunk method developed by Logistic Distro-Data, Inc. for the Lockheed-Georgia Company (ref. 13). The medium density study IOC to passenger revenue ratio was 0.58, and was based on North Central Airlines data for a 1973-74 four-quarter period. This ratio is high as an IOC predictor if the entire group of regional airlines used for the study is considered. This ratio is summarized in Figure 3-2, and shows that 1973 operations produced a range of values from 0.50 (Allegheny) to 0.61 (Hughes Airwest). A weighted average for 1973 for the group of airlines shown in the figure is 0.54. This difference in the ratio, if applied to the MDS passenger revenue value $290.52 million, would reduce the $168.5 million IOC by $11.6 million, and could impact the profit and loss analysis of that particular short-haul airline simulation.

3.3 Airline Critique

Two airlines of diverse operating characteristics were retained as consultants for the study to ensure that the operating cost analysis and the resultant cost model were realistic from an airline point of view. These airlines were Air California, an intra-state carrier, and United Airlines, an inter-state, domestic trunk airline. Their comments and critiques (ref. 14 and 15) have been summarized below.

Air California. Air California found the basic study assumptions to be reasonable, and the cost parameters applicable to the evaluation of future short-haul operating economics. A suggestion was made to check the 1973 CAB fare study to determine the length of service life used for calculating depreciation, but the comment was made that the treatment of lease and depreciation regarding flight equipment was good. The airline noted that, at the present time, a good check of DOC and IOC is a 1:1 ratio, with IOC increasing at a faster rate. This agreed with the results and trends determined during the course of the study.

United Airlines. United Airlines evaluated the short-haul operating cost model from the point of view of how, if at all, they would use a "standard" cost model of the type developed during the study. It is their contention that a "standard" method for determining DOCs and IOCs is not the best method for providing comparative aircraft cost values and that their applications can sometimes produce inaccurate results and conclusions. Based on their extensive and detailed cost history, United Airlines would never use a "standard" method of cost estimation to compare the operating economics of competitive aircraft to make an aircraft purchase decision or to determine route suitability. They would use instead their own internally developed methodologies based on their own aircraft operating cost histories.

The airline critiques summarized above represent quite diverse points of view. This is not surprising when considering the type of operation of each. To get a proper perspective on the usability of the type of short-haul operating cost model developed as part of the study, all domestic trunks, regional airlines, and intra-state carriers should review the model. This was beyond the scope of this study.

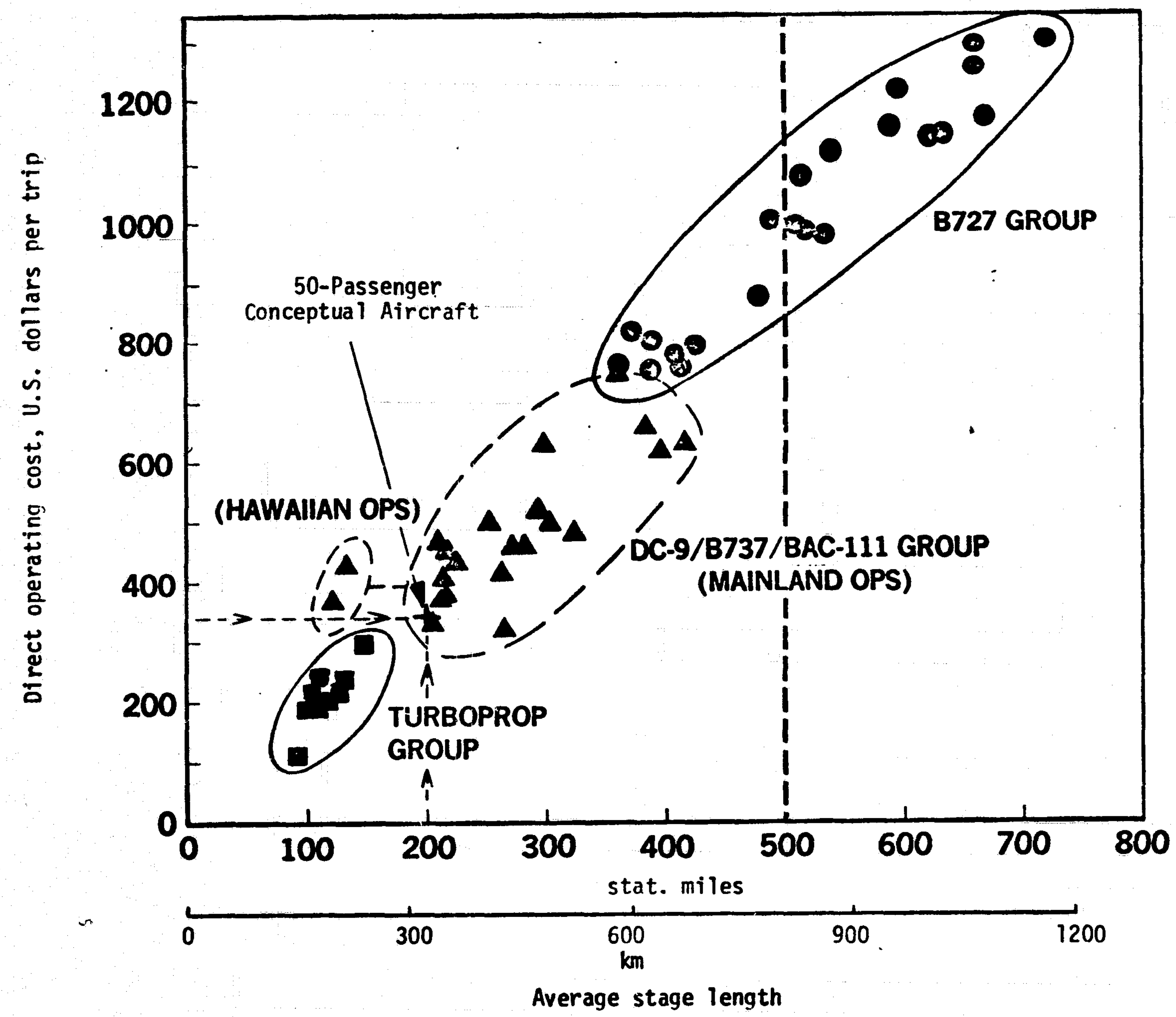

Figure 3-1. - Trip cost comparison - 50-passenger conceptual aircraft, 1973 dollars

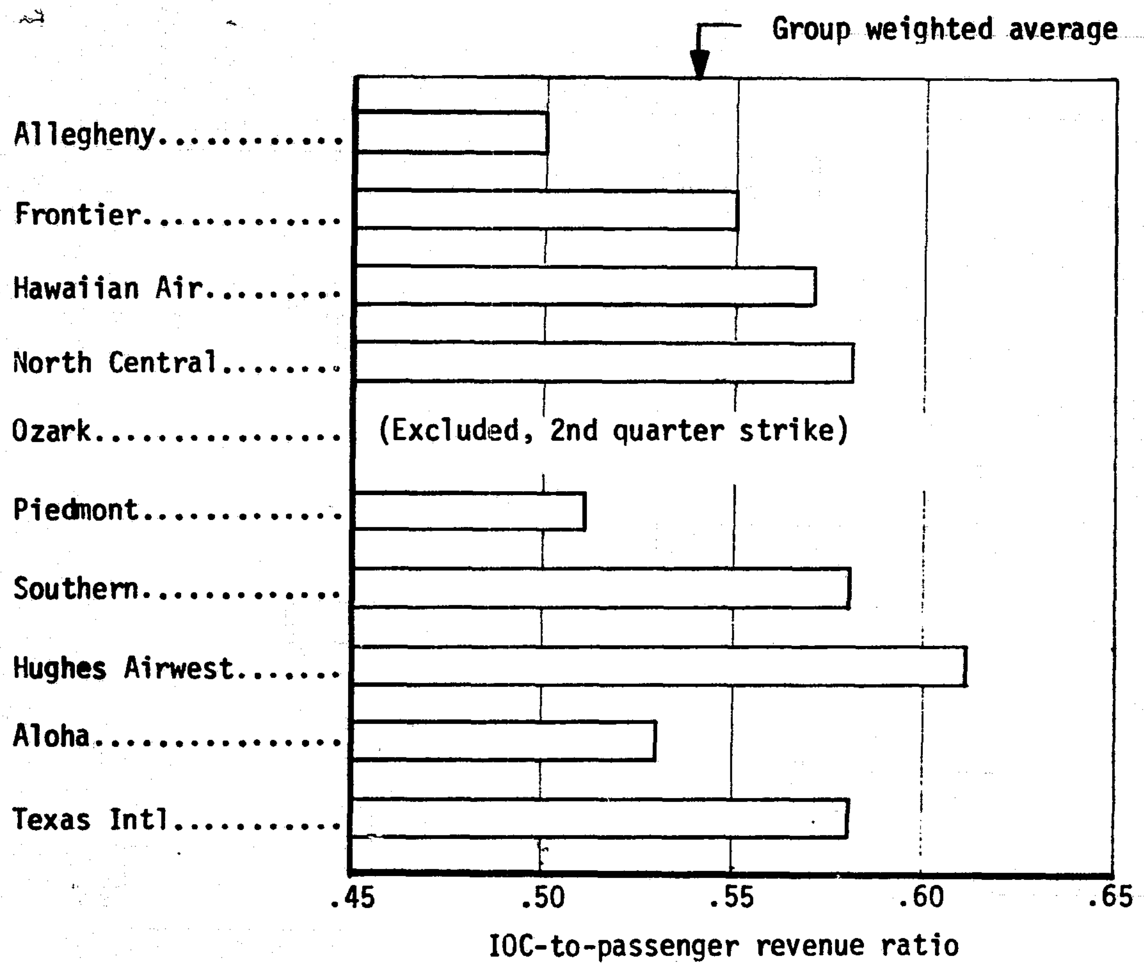

Figure 3-2. - Regional airlines IOC-to-passenger revenue ratio

[1973 operations]

TABLE 3-1

CONCEPTUAL SHORT-HAUL AIRCRAFT-AIRLINE INPUTS[a]

(Cost inputs in 1973 dollars)

Parameter	Value	Units
Aircraft type	turbofan	--
DPC	50	seats
TOGW	44,000	lb
LGW	40,000	lb
MWE	25,700	lb
W_a	23,800	lb
W_e	950	lb
N_e	2	--
TSLS	8,000	lb
ESHP	(not applicable)	
C_t	3,300,000	$U.S.
C_e	400,000	$U.S.
IR	.015	(1.5% ÷ 100)
VDC	479	mph
FCR	800	USG/blk. hr.
C_f	.14	$U.S./USG
FS	60	aircraft
ASL	200	stat. mi.
BTPF	.72	hours
FTPF	.60	hours
ADPY	3,917	--
RAD	235,000	--
RABH	2,820	(per aircraft)
RAM	47×10^6	(stat. mi.)
ERP	7.05×10^6	--
LF	.6	(60% ÷ 100)
RPM	1410×10^6	(stat. mi.)
RTM	157×10^6	(.1113 x RPM)

[a] U.S. Customary Units required for model

TABLE 3-2

CONCEPTUAL SHORT-HAUL AIRCRAFT-AIRLINE COST OUTPUTS
(1973 dollars)

Cost element		Millions of U.S. Dollars
Direct operating cost		
Flight crew	FCE	20.66
Fuel, oil and taxes	FOT	19.80
Insurance	INS	2.97
Airframe direct maintenance, turbofan	ADMTF	6.30
Airframe labor content, turbofan	ALCTF	2.95[a]
Engine direct labor, turbofan	EDLTF	2.45
Engine maintenance, materials, turbofan	EMMTF	2.46
Applied maintenance burden.	AMB	10.16
Depreciation-flight equipment	DFE	15.71
	DOC	80.51
Indirect operating cost		
Cabin attendants	CAE	4.86
Beverage-only	BOE	.19
Other passenger service	OPSE	2.44
Aircraft control and line servicing	ACLSE	10.21
Aircraft landing fees	ALFE	1.59
Traffic servicing	TSE	23.98
Promotion and sales	PASE	16.90
Ground property and equipment	GPEE	3.20
GPEE depreciation content	GPDC	1.31[b]
Amortization	ADPE	.80
General and administrative	GAE	7.66
	IOC	71.83
Total operating cost	TOC	152.34

[a] Non-additive for DOC

[b] Non-additive for IOC

TABLE 3-3

COST MODEL VERSUS AIRLINE COMPARISON

1973 OPERATIONS; 1973 DOLLARS

ACTUAL	ENPLANED REVENUE PASSENGERS (M)	REVENUE PASSENGER MILES (M)	REVENUE AIRCRAFT MILES (M)	DIRECT OPERATING COST ($M)	INDIRECT OPERATING COST ($M)	TOTAL OPERATING COST ($M)
ALLEGHENY	10.84	3,302.0	84.92	160.17	149.22	309.39
HUGHES AIRWEST	3.67	1,292.3	30.99	57.08	66.74	128.82
FRONTIER	3.38	1,308.9	34.98	57.69	58.28	115.97
NORTH CENTRAL	4.26	1,011.5	29.42	53.56	60.85	114.41
TYPICAL AIRLINE	7.05	1,410.0	47.0	80.51	71.83	152.34

TABLE 3-4

DOC METHOD COMPARISON -- 50-PASSENGER CONCEPTUAL AIRCRAFT

(1973 dollars)

60-aircraft fleet size results, millions of dollars per year:		
DOC Cost Element	Medium Density Study DOC Model (ref. 12)	Short-Haul Operating Cost DOC Model
Flight crew	24.53	20.66
Insurance	1.98	2.97
Depreciation	12.54	15.71
Fuel	18.95	19.80
Maintenance, Direct	11.70	11.21
Burden	8.10	10.16
Total DOC	77.85	80.51

TABLE 3-5. COST METHOD COMPARISONS

[Millions of 1974 dollars]

Operating Cost Categories	Industry Formula, DAC-Modified	Medium Density Study Formula	Short-Haul Economic Formula
Direct	156.8	136.8	142.6
Indirect	425.5	168.5	153.1
Total	582.3	305.3	295.7

FLEET DATA:

- o 50-passenger turbofan aircraft
- o Fleet of 131 aircraft
- o 570,000 annual trips
- o Midwestern Regional Market

4.0 COST MODEL APPLICABILITY

4.1 Estimating Capability

The short-haul operating cost model is capable of providing realistic system-level costs of a typical short-haul airline similar to the regional carriers which were the basis for the model. The model facilitates the evaluation of some of the primary short-haul factors from an operational point of view. The model can be used for comparative analysis of aircraft and airline operational concepts. It can also be used for sensitivity studies.

4.2 Constraints

The limitations of the model must be known to properly interpret its results. Some of the more important limitations are included from earlier discussions. The model

(1) Is not designed as a forecasting tool.

(2) Uses existing, contemporary aircraft to form aircraft-related cost elements. The ability of the model to evaluate advanced technology is a judgmental factor to be decided by the user.

(3) Replicates regional airline operation. It is not recommended for prediction outside the sample represented by regional airline operations and expenses. It is also not meant for evaluation of domestic trunks, intra-state airlines, or commuter operators since the requirements to evaluate these airlines would obviously represent a different type of model. In reference to the regional airline base of the model, the following ranges of calendar year 1973 operating and financial statistics are tabulated to point out the magnitudes involved:

Enplaned revenue passengers	2M to 11M
Revenue passenger-miles (-km)	250(267)M to 3,300(3,528)M
Revenue aircraft-miles (-km)	3(3.2)M to 100(107)M
Total operating costs	$20M to $310M
Passenger revenue	$20 M to $300M

(4) Does not discriminate between differences in route densities within the airline represented.

(5) Is not intended to be an airline efficiency analyzer, although in some respects it could be, with proper usage.

(6) Is not an airline financial model since it works only with operating costs.

(7) Has not been thoroughly tested; that is, it has not been evaluated by each regional airline to determine if all of the appropriate variables are included in each equation and that the model is representative of short-haul operations.

(8) And its CERs could change if different base years were used.

A detailed time series analysis of every CER and its coefficients was beyond the scope of the study, and thus a model checking (or maintenance) function is a necessary requirement. Again, it must be remembered that the model describes a regulated, oligopolistic service industry, and any change in the attributes of that type of industry would affect the model's cost estimating capability. A model maintenance process, then, is up to the analyst, for it cannot be predicted when or how the model becomes obsolete.

4.3 Expansion Capability

There are several directions in which this model can be expanded. The first natural extension would be to apply the same model logic to other airline groups, data permitting. This same type of model designed for the group of domestic trunks, intra-state, and commuter airlines would permit a relative comparison of expense elements.

Another expansion, again data permitting, would be a model built from functional factors and utilizing more detailed data. This model could assess costs for individual airplane types or specific route structures. This model may not be cost-effective if the broad operating base is to be evaluated. It is suggested that selected cost elements be developed using a more detailed data base.

The multi-year analysis, also discussed previously, can also be considered to be an expansion item. It would be more logical to develop the effects of inflation factors on the various cost elements than to treat the end results by an inflation factor.

5.0 AUTOMATION IMPACT ON SHORT-HAUL OPERATING COSTS

The automation analysis discussed here completes the two-part evaluation of that subject which was conducted during the six-month study of short-haul aircraft operating economics. The first part, described in Section 1.4.5 of this volume, was an analysis of ground servicing expenses pertaining to station operations of the regional airlines. The results of this first phase necessitated a re-direction of the automation study effort from a detailed, cost-benefit analysis of the automation effect on certain airline functions to a more gross evaluation on a total-airline basis. The relationship of the station cost analysis, the automation analysis and the short-haul IOC model was shown in Figure 1-3.

The most probable functional airline operations which might benefit from automation, what the expected cost impact might be, as evaluated using the conceptual airline example shown in Section 3.0, and the significant findings relevant to automation in short-haul operations will be discussed.

5.1 Areas For Automation

Probable areas for automation will be based on those functional areas of airline operation which have the greatest impact on total operating cost. The functional operating cost distribution for the local service airlines for 1973 (Figure 5-1) served as the basis for the conduct of this phase of the automation analysis. In order of decreasing contributions to TOC, seven functions were selected for evaluation:

(1) aircraft and traffic servicing

(2) flight equipment maintenance

(3) flight crew

(4) promotion and sales

(5) fuel, oil and taxes

(6) flight equipment depreciation and rentals

(7) passenger service

5.1.1 Aircraft and Traffic Servicing. Those functions most discussed and evaluated are baggage handling at the airport terminals, passenger check-in and boarding, and flight planning and control. Baggage handling mechanization or automation development is lagging behind other passenger-related functions even though mishandled baggage is one of the chief sources of airline passenger complaints. Manual baggage handling, including using carts, tractors, and static display racks, still is the most economical and effective system for low-density airports. On the other hand, mechanizing operations with a belt loader and recirculating display unit increases costs without any measurable improvements in processing items. The intensified security and baggage inspection procedures further aggravated baggage handling problems and the attendant passenger check-in problem. The initial and most prevalent use of automated equipment in this area has been for baggage sorting, but a real barrier to the broader use of automated baggage handling equipment is the widely divergent configurations of airports throughout the United States. Also, optimum systems vary with the individual requirements of airlines and terminals within their route system, and with high-, medium-, or low-density operations. Due to this diversity in terminal configurations, airline requirements, density impacts, and the lack of industry-wide methods and standards, the cost of baggage handling equipment has remained very high. Each airline has in turn developed its own methods and standards which may

or may not be compatible with the total operations of a particular airport. This has produced inefficiencies in labor utilization.

The existing automated baggage handing systems have not exhibited the requisite reliability to warrant wide-spread interest in any one unit. Even in the new airport terminals, needlessly complex architectural designs have resulted in complicated baggage flow patterns that have inhibited the overall operating performance of the systems, thus contributing to the poor system reliability. Reliable systems should have the potential of decreasing the amount of misdirected and damaged baggage. Until reliable automated baggage systems can be better standardized and more easily made and installed, the high cost of these systems will outweigh the benefits generated at all but the very high-traffic and high-frequency airports. All these reasons have caused the airlines to give top priority to the study and implementation of automation in this function.

Automation can also improve passenger check-in and boarding through computer-aided seat assignment and selection and boarding pass printing. Airlines, however, have found that automated seat selection and boarding pass printing are presently not worth the capital investment they require. These two customer-oriented functions, because of no cost-reducing capability, will lag behind in general implementation by the airlines.

Several aircraft control operations have been automated. Computers are used to tell flight dispatchers the planes that are flying and where, the weather they're approaching, and how much fuel they have. Computer-assisted flight planning is used to optimize fuel usage and flight time. This function has become increasingly important during the recent fuel allocations and

shortages and continuously rising fuel costs. The computerized fuel usage and flight planning would impact the fuel, oil, and taxes DOC element.

5.1.2 Flight Equipment Maintenance. Flight equipment maintenance, which includes labor, aterial, outside services and allocated burden, was the second largest expense item for the regional airlines in 1973, consuming 16.5 cents of every operating dollar. Automation has been shown to work effectively in this function to offset the steady rise in labor and material costs. The high purchase cost of wide-bodied aircraft has made it expedient that the airline justified the expense involved in buying and using new automated test equipment and the computer in order to keep these airplanes flying and producing revenue. In this area, most of the major airlines are saving maintenance-related dollars by:

(1) Using computers to keep track of aircraft condition, time between overhauls, spare parts and materials.

(2) Using new automated test equipment to aid in repair analysis and cut maintenance requirements, and using computers to collect and account manpower used in maintenance.

(3) Extensively using jigs and automatic component access and handling systems.

Particularly with the wide-bodied transports used by the trunk airlines, improved airplane condition diagnosis and procedures have been shown to reduce subsystem shutdowns and resultant delays. This translates into greater aircraft utilization and thereby improved revenue-earning potential per aircraft.

C.3

5.1.3 Flight Crew. The flight crew expense for regional airlines for 1973 consumed 14.2 cents of every operating dollar. The scope of this study did not permit an extensive analysis of this direct operating cost element where the relationship between airline route system, aircraft types operated, and flight schedule could be quantitatively assessed. Although only indirectly related to short-haul operations, some domestic trunks are using extensive real-time data processing systems to track and control their entire aircraft fleet and flight crew movements and requirements in order to more cost-effectively control a very high unit labor cost item. The major problem for those trunks and regionals using these types of computer systems is that the hardware and software are not as readily interchangeable between airlines as are the more easily shared reservations systems. As a result, each airline takes a different approach to automating flight crew schedules, and any savings relative to the group of airlines as a whole, whether it be trunks or regionals, are not easily identified.

5.1.4 Promotion and Sales. This airline function has probably been impacted by automation more than any other; to date, total automation is almost complete for reservations, and automated ticketing is not far from becoming a normal procedure. Automated reservations and ticketing are cost-effective even for low-traffic-density stations within an airline's route network because the whole airline system has access to and can use this capability. One airline has experienced a 15 to 20 percent increase in the productivity of their reservations personnel because of automation. This productivity increase is due to the reduced average telephone time required per reservation because of faster, computer access to essential data including fares, flight information, and seat availability. All U.S. trunk and local

service airlines, some intra-state certificated carriers, and a dozen of the largest commuter airlines have some form of computer-aided reservation system, wither wholly-owned or time-shared on a multi-host basis. For example, Air California was able to cut the cost per reservation substantially by using a multi-host reservation system; by contracting with PARS (Programmed Airline Reservations System), they were able to reduce their cost per reservation from $1.25 in 1970 to $0.95 in 1974.

In addition to reservations, automated passenger processing has spread to such functions as fare quotation and itinerary pricing, computer ticket printing, terminal and telephone flight information, seat assignment/selection and boarding pass printing. It is now possible to obtain from the computer almost all fare calculations including joint fares (interline) quotations. These fare quotations have proved to be much more accurate and consistent than manually calculated fares. Computerized ticket printing has been placed at those airport terminals where the need to speed ticket-counter passenger processing is the greatest. The reliability and readability of these automated printers is very important in gaining customer confidence in machine-printed tickets. A majority of the trunks and several of the local service airlines now have various types of computerized ticket-printing systems, with some of these systems also incorporating a fare-calculation capability.

To speed up ticketing, the use of credit cards to purchase tickets at the automated ticket machines has been implemented by several of the trunk and local service airlines. This does require, however, an accurate credit checking system in order to be cost-effective.

The types of automated ticketing systems described here will find their way into more widespread airline operation, as the carriers strive to increase the number of passengers handled per employee and to increase the speed with which the passengers get their tickets.

5.1.5. Overview. The various applications of automation to airline operations just discussed apply both to trunks and to regional airlines. Based on the information reviewed and evaluated during the study, a clear demarcation between the two carrier groups was difficult to make in each and every operational function. As a result of this, and the fact that the CAB Form 41 data did not provide a good basis from which to conduct a comprehensive cost-benefit analysis, the cost impact of automation on short-haul operating costs was evaluated on a very generalized basis. These results are presented in the following section.

5.2 Cost Impact of Automation

The expected reduction in short-haul total operating cost would be relatively small (2 to 3 percent), based on the results of a case study conducted during the automation evaluation phase. A qualitative assessment of the short-haul airline used for the illustrative example in Section 3.0 of this volume determined that this saving would occur in four functional cost elements: flight equipment maintenance, flight equipment depreciation, traffic servicing, and promotion and sales. The results are summarized in Table 5-1, and are explained below. The sample airline used in the case study had a 60-aircraft fleet and a \$152.34 million annual TOC (\$80.51 million DOC and \$71.83 million IOC). In terms of actual dollars, the 2.61 percent savings would amount to about \$4 million per year; but this was a qualitatively determined value, and its impact should be evaluated with that in mind.

5.2.1 <u>Direct Operating Costs</u>. The estimated 1.35 percent reduction in DOC resulted from reductions in maintenance (1.0%) and depreciation (0.35%). The benefits of using automated equipment in the maintenance function has been in terms of dollars saved. These savings have primarily offset rising labor costs rather than generating lower annual maintenance costs. However, if a reasonable reduction, say five percent, in maintenance labor costs could be achieved, the resulting impact on DOC for the fleet of 60 aircraft would be one percent. Total operating costs would be reduced by one-half of one percent. No improved maintenance techniques resulting from automation offer the potential to reduce spares inventories and to increase aircraft utilization, but the impact on total flight equipment depreciation costs would be minimal. For example, by reducing spares from 12 percent (the cost model average value) to 10 percent in the example presented in Section 3.0, annual depreciation expenses for the fleet of 60 aircraft would be reduced by 1.8 percent. Total direct operating costs would be reduced by less than one-half of one percent and total operating costs by almost two-tenths of one percent. Increased aircraft utilization reduces depreciation expenses on a per-aircraft-block-hour basis, but not on an annual fleet or system basis. These two cost reductions resulted in the 1.35 percent savings in DOC shown in Table 5-1.

5.2.2 <u>Indirect Operating Cost</u>. The application of automation to airline operations has more directly benefited the functions generating indirect operating costs. These savings have been realized either as actual dollar savings or as an offset to additional labor expenses through improved employee productivity. Indirect functions offering no measurable gains from automation include passenger service, maintenance and depreciation of ground property and equipment, and general and administrative services.

Traffic servicing includes the expenses of passenger and baggage handling. Benefits from automation in these functions have been primarily in terms of more passengers or baggage handled per employee. Further automation gains in this area are given the highest priority by most airlines, and therefore, an optimistic ten percent reduction in costs is assumed. This reduction would decrease indirect operating costs by 3.6 percent and total operating costs by 1.7 percent.

Promotion and sales expense includes reservations and sales costs as well as advertising and publicity expenditures. The reservations and sales function has been most affected by automation. Significant gains in productivity per employee and in actual dollar savings have been achieved. The 1973 airline industry indirect operating costs reflect most of the savings from automation in this area. However, if a further reduction in promotion and sales costs of five percent can be generated, the indirect operating costs could be reduced by 0.45 percent, thereby resulting in a 0.21 percent reduction in total operating costs. Advertising and publicity expenses are directly influenced by managerial policy and the degree of competition among the airlines and do not present opportunities for any noticeable gains in cost reduction due to automation. The estimated cost reductions in traffic servicing and in promotion and sales provided the 4.05 percent reduction in IOC shown in Table 5-1.

5.3 Automation Impact Summary

The total financial impact of automating any function must be comprehensively evaluated by the airline before it can make a rational decision regarding a particular system's acquisition and implementation. Not just the

initial costs of the system but also its operating and continuing (add-on capability) costs, which should reflect its maintenance and reliability characteristics, must be estimated and evaluated. Airlines have not always been able to make a direct translation of automation benefits into improved economics. While as a rule most computer functions do show a significant net savings, others do not. In fact, often the improvement may be measurable only in terms of better service for the passengers. In addition, any automated equipment procurement decision by an airline should be commensurate with the level of customer service desired, and must also be within the financial capability of that airline.

Generalizations were made regarding what cost benefits might accrue from additional automation over and above what currently exists in airline operation. No quantitative conclusions could be made, nor could any precise system acquisition forecasts be made, particularly with regard to short-haul airlines.

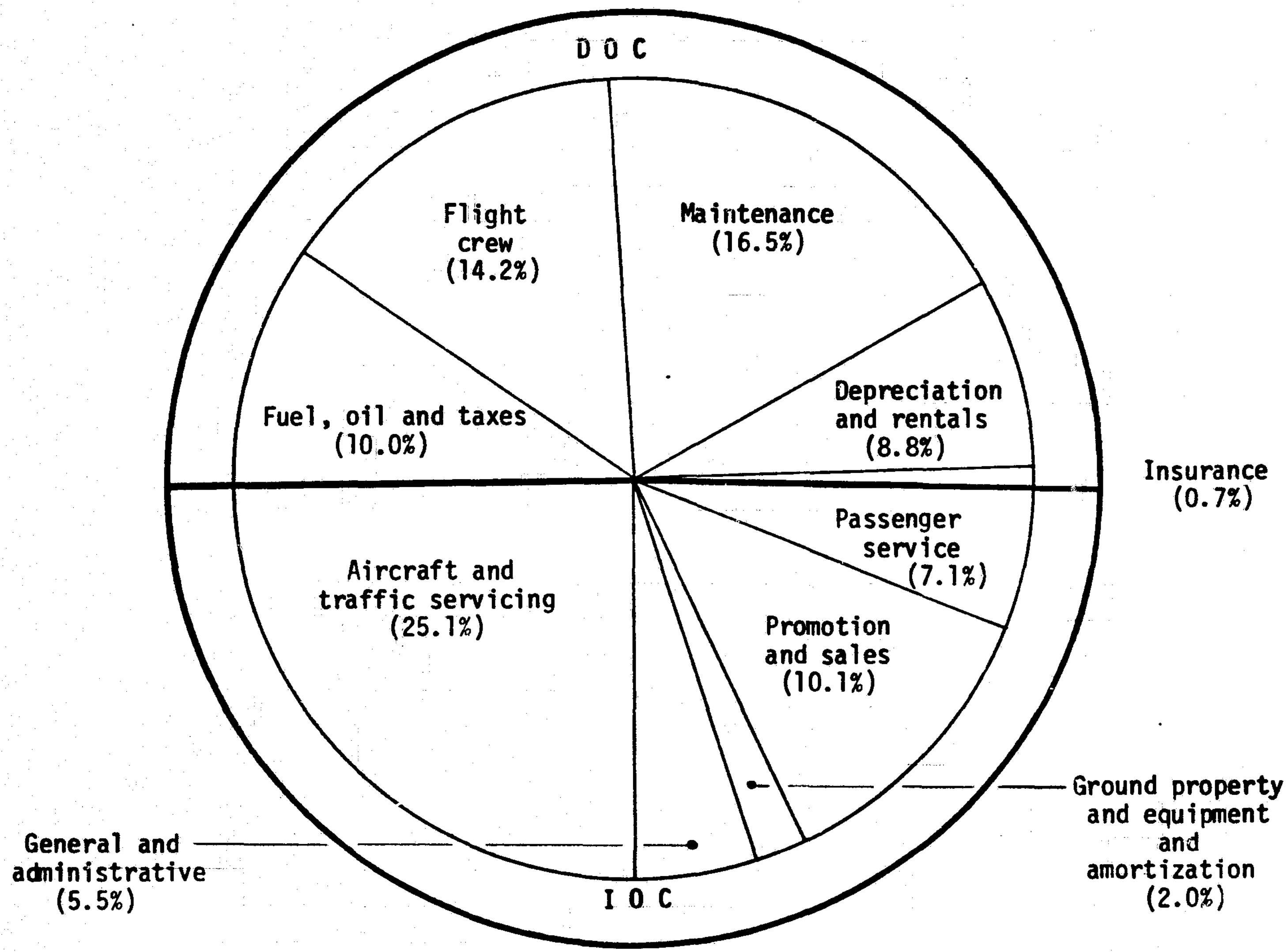

Figure 5-1. - Distribution of total operating costs--1973
[Local service airlines]

TABLE 5-1

TOTAL ANTICIPATED AUTOMATION SAVINGS

	PERCENT SAVINGS	PERCENT OF TOC SAVINGS
DIRECT OPERATING COSTS		
DEPRECIATION	.35	.20
MAINTENANCE	1.00	.50
TOTAL DOC	1.35	.70
INDIRECT OPERATING COSTS		
TRAFFIC SERVICING	3.60	1.70
PROMOTION AND SALES	.45	.21
TOTAL IOC	4.05	1.91
TOTAL OPERATING COST SAVINGS (PERCENT)		2.61

6.0 CONCLUSIONS AND RECOMMENDATIONS

The objectives of the six-month study were primarily, (1) to develop an improved capability for analysis of the operating economics of short-haul air transportation; and (2) to identify the effect of factors such as level of service provided, traffic density of the market, stage length, number of flight cycles, level of automation, and other operational factors on direct (DOC), indirect (IOC), and total (TOC) operating costs. The study, designed to meet the above objectives, was of an analytic research type.

6.1 Summary of Results

This is the first model developed for determining operating costs of short-haul air transportation systems. It thus gives improved capability over the 1967 ATA DOC method and the 1964 Lockheed-Boeing IOC methods which were specifically for domestic trunk, long-haul operations. The model constructed from CAB Form 41 data for aircraft types ranging in size from the DHC-6 (Twin Otter) class to the B-727 class, and for regional airlines ranging in size from Aloha to Allegheny.

The model parallels the forementioned DOC and IOC methods in the types of operating costs measured; however, it cannot be compared, item by item, to either method since it is more detailed in character, and it uses different variables as inputs. It produces proper results when provided with input data appropriate to the short-haul environment; that is, aircraft that are short-haul in design orientation and that are operated at average stage lengths of less than 500 statute miles (805 km).

The model can evaluate (1) level of service changes in passenger service expense, as exemplified by the difference in a food-and-beverage and

a beverage-only operation; and (2) the effect of changes in stage length based on aircraft performance data inputs; block fuel and block time (or speed) for each stage length under study. The model, and its substantiating analyses, do not corroborate the 1967 ATA maintenance cost premise of flight-hour and flight-cycle related components. This might not be possible because of the system-level approach taken and the types of aircraft used as the study base. This difference is an area for future study.

The operating economics of the regional airlines could be improved approximately three percent by automation, but these improvements are contingent on so many assumptions that no specific recommendations regarding technology impact can be substantively made. The Form 41 data used for the study did not provide the type of information required to conduct an extensive cost-benefit analysis of automation as it impacts the regional airlines.

6.2 Recommendations

Since this was the only known effort to model the operating costs of regional, short-haul, aircraft-airline operations, two types of follow-on studies are recommended, based on the knowledge gained from the current study. These two types of studies can be categorically separated into similar system-level studies of other types of airline operation, the same type, and into in-depth analyses of specific cost elements. The latter types will be discussed first.

In-Depth Studies. These would expand the analytic depth of the cost elements of flight crew expense, flight equipment maintenance, and some operational expenses, as follows:

Flight Crew Expense

- Investigate, in detail, the effects of the type of route system, aircraft scheduling and route assignment, and flight crew scheduling on the number of flight crews required and their expenses.

- Analyze and compare the differences in flight crew composition, caliber, and compensation between commuter, intra-state, local service, and domestic trunk carriers.

Flight Equipment Maintenance

- Examine the airframe cost differences between turboprop and turbofan type aircraft. One equation such as the 1967 ATA method for both airframe types is not adequate as the short-haul operating cost study produced evidence of unexplainable variations between aircraft types.

- Determine the effect of airline maintenance experience on airframe and engine maintenance costs. Examine the rate of time-related maintenance improvements within and between aircraft designs (e.g., short-haul, medium-haul, long-haul).

- Determine the effect of technological age and actual aircraft age on airframe maintenance costs. Identify the primary reasons for cost differences between series types within a particular model (e.g., 727-200 vs. 727-100, DC-9-30 vs. DC-9-10, FH-227 vs. F-27).

- Determine what factors other than price, weight, and thrust (or horsepower) are available during the aircraft concept formulation process to better evaluate and predict aircraft maintenance costs.

Passenger Service

Determine the average percentage of flights receiving food service. Correlate food service types to length of passenger journey, time of day and carrier type. Compare domestic trunks to regional carriers.

Aircraft Servicing

Determine the correlation of type of route system, aircraft routing pattern, and maintenance and servicing concept on aircraft servicing expense. Compare trends between carrier types, both within a group (i.e., the domestic trunks), and between groups (trunks vs. regionals).

Traffic Servicing

Correlate the type and number of line stations (i.e., turnaround, through-stop, etc.) within a carrier's route system and its traffic servicing expense. Determine the cost impact of these correlations for both regional and trunk airlines, and identify and analyze the significant cost variances.

System-Level Studies. These would develop an operating cost model for the domestic trunks using the same analysis techniques as those developed for the regional airlines, and using the same data base, the CAB Form 41 accounts.

- Provide an up-to-date methodology for predicting trunk-level operating expenses, and, if patterned after the short-haul cost model, provide a basis for an element-by-element comparison between the two types of operations.

- Develop an operating cost model for the intra-state and commuter airlines. Obtain and analyze operations and expense data for representative intra-state and commuter airlines. Allocate the operating expenses to conform as nearly as possible to the CAB Form 41 accounts.

- Develop appropriate cost-estimating relationships, for each of the four air carrier groups (trunks, regionals, intra-state, and commuter), for a common set of operating cost elements. Compare the four operational cost relationships.

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